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PROGRESS REPORT

of

RESEARCH

THE FOREST SERVICE

This progress report includes the research accomplishments of the Forest Service and cooperators from July 1, 1967, through June 30, 1968. The report is for the use of scientists and administrators in program coordination, development and evaluation; and for the use of advisory committees in program review. This report and the recommendations of advisory committees aid in concentrating available research resources on the more pressing problems, maintaining a proper balance between short and long-range objectives, and coordinating the research efforts of the Department and that of the State Experiment Stations, Universities, Colleges of Forestry, the forest-based industries, and privately supported research institutions.

The report includes both descriptions of completed research and statements of progress. Completed accomplishments are described in detail in the publications that are listed in this report. This report is not intended for publication and should not be used in citations.

Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs. This progress report was compiled in the Forest Service, U. S. Department of Agriculture, Washington, D. C. 20250.

UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C.

July 1, 1968

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ROCKY MOUNTAIN STATION

FOREWORD

Research by the Forest Service and cooperators contributes to the knowledge and technology that is required for effectively and efficiently managing all the Nation's forest and range lands for goods and services. Research accomplishments provide a reservoir of information, ideas, concepts, and techniques that we can use for knitting together the various interests in resource management and for improving the quality of our total environment. The multiple use and sustained yield principles are more effectively put into action with the use of research derived techniques. Current research intelligence provides us with the information needed for maintaining an acceptable balance between production demands and the known capacity to produce timber, watershed, recreation, wildlife habitat and range outputs. The development of new technology, and the discovery of new knowledge, gives us alternative ways to increase efficiency, reduce resource requirements, maintain relatively stable prices and create new rural investment opportunities.

Research outputs are intermediate in the chain of resource activities that lead to end products. Research does not build houses except for experiment. But, a thousand low-income families put into adequate homes can be the product of activities that used research inventions for lowering the cost and improving the adequacy of houses. Many research outputs are used repeatedly and often contribute to joint products. For example, research on percolation of water through soils may be used by a resource manager to increase the water supply for a number of different communities, increase timber production and renovate a trampled recreation area. Outputs have not been valued in dollar terms in most cases because of the difficulty of assigning dollar values to resource products and services that are not marketed through commercial channels and the difficulty of relating research expenditures to components of multiple outputs. Research outputs are valued in terms of their relative contribution toward achieving executive and administrative goals and meeting our social, political, and economic needs and desires.

In this report, accomplishments for fiscal year 1968 are identified by research problem areas. These areas are described in a National Program of Research for Forestry which relates forestry research in the Department of Agriculture to that at the State Agricultural Experiment Stations, and other schools participating in the McIntire-Stennis Program.

Eight Forest and Range Experiment Stations and the Institute of Tropical Forestry serve the regional research needs of the Nation. Research in forest products utilization is done mostly at the Forest Products Laboratory in Madison, Wisconsin, although forest products research is also done through the Stations. The number of scientist man-years devoted to areas of research are listed in tables in the report. The tables show locations of scientists by States but the programs are regionally and nationally oriented. A scientist man-year is the equivalent of one year's time of a research scientist who is professionally trained and has responsibility for planning and doing research.

A list of publications is given at the end of each area of research. Copies of most of these publications are available from the Stations. The following map shows the Station territories and the research work unit locations. For publications, information and service, persons in these respective territories should contact the Director:

Pacific Northwest Forest and Range Experiment Station,
809 NE 6th Ave., P. O. Box 3141, Portland, Oregon 97208

Pacific Southwest Forest and Range Experiment Station,
1960 Addison St., P. O. Box 245, Berkeley, Calif. 94701

Intermountain Forest and Range Experiment Station,
507 25th St., Ogden, Utah 84401

Rocky Mountain Forest and Range Experiment Station,
240 West Prospect St., Fort Collins, Colo. 80521

North Central Forest and Range Experiment Station,
Forest Service, U. S. Dept. of Agriculture. Folwell, Ave.,
St. Paul, Minnesota 55101

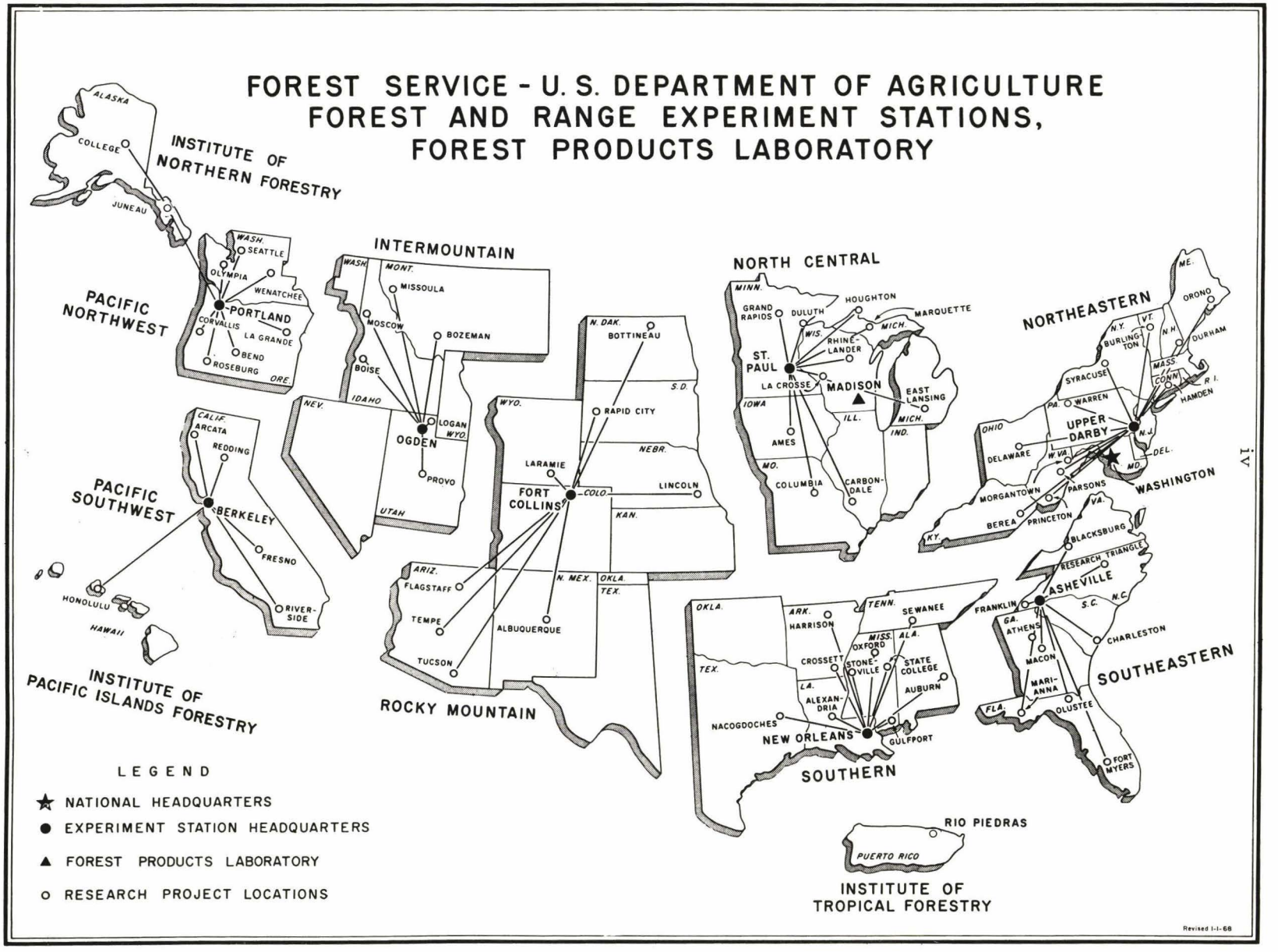
Northeastern Forest and Range Experiment Station,
6816 Market Street, Upper Darby, Pa. 19082

Southeastern Forest and Range Experiment Station,
Post Office Building, P. O. Box 2570, Asheville, N. C.
28802

Southern Forest and Range Experiment Station,
T-10210 Federal Bldg., 701 Loyola Ave., New Orleans, La.
70113

Forest Products Laboratory, North Walnut St., P. O. Box 5130,
Madison, Wisconsin 53705

Institute of Tropical Forestry, University of Puerto Rico
Agricultural Experiment Station Grounds, P. O. Box AQ,
Rio Piedras, Puerto Rico 00928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FOREST PRODUCTS LABORATORY
ALASKA
COLLEGE
JUNEAU
INSTITUTE OF NORTHERN FORESTRY
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SEATTLE
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INTERMOUNTAIN
WASH.
MONT.
MISSOULA
MOSCOW
BOZEMAN
BOISE
IDAHO
NEV.
OGDEN
LOGAN
WYO.
PROVO
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LEGEND
NATIONAL HEADQUARTERS
EXPERIMENT STATION HEADQUARTERS
FOREST PRODUCTS LABORATORY
RESEARCH PROJECT LOCATIONS
Revised 1-1-68

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TIMBER MANAGEMENT RESEARCH

SILVICULTURE

USDA and Cooperative Program

Location of Intramural Work	Scientist Man-Years F. Y. 1968			
	Research Problem Area			Total
	111	101	102	
Oregon	12.0			12.0
Washington	7.0			7.0
Alaska	4.0			4.0
California	6.0			6.0
Hawaii	4.5			4.5
Idaho	5.0			5.0
Montana	4.5			4.5
Utah	1.0			1.0
Colorado	3.0			3.0
Arizona	3.0			3.0
South Dakota	2.0			2.0
Wisconsin	2.0			2.0
Minnesota	6.7			6.7
Michigan	8.0			8.0
Iowa	2.0			2.0
Illinois	5.0			5.0
Missouri	3.5			3.5
Maine	4.0			4.0
West Virginia	2.0			2.0
New Hampshire	3.5			3.5
Pennsylvania	1.0			1.0
Kentucky	2.0			2.0
Maryland	3.0			3.0
Virginia	2.0			2.0
North Carolina	3.8	1.0	2.0	6.8
South Carolina	5.0			5.0
Georgia	7.0			7.0
Florida	7.0			7.0
Arkansas	6.3			6.3
Louisiana	11.4			11.4
Alabama	3.3			3.3
Mississippi	10.8			10.8
Tennessee	3.9			3.9
Texas	1.1			1.1
Puerto Rico	2.3			2.3
Total	158.6	1.0	2.0	161.6

Intramural program is supplemented by extramural support representing (a) 0 SMY's at State Agricultural Experiment Stations, (b) 0 SMY's at other U.S. institutions, and (c) P.L. 480 funds in 7 countries representing $135,266 U.S. dollars equivalent.

Problems and Objectives

The broad field of silviculture includes the problems of growing and tending forest trees and stands from seed to sawtimber. It deals with reproducing forests both naturally and artificially with intensive cultural measures for increasing the yield and improving the forest stands, with methods for evaluating and improving the productive capacity of forest soils, and with stand treatments required to perpetuate valuable species adapted to the site. Related to all of these problems are the basic physiological processes involved in tree growth.

Major objectives of research are to develop and evaluate alternative ways to:

1. Reduce the shortage of high-value hardwoods.

2. Increase the efficiency of softwood production.

3. Develop the silvicultural base for multiple-use management.

Progress - USDA and Cooperative Programs

RPA 111-TIMBER MANAGEMENT

A. Site Evaluation and Soil Improvement

A study to determine which species are best suited to a particular site in the upland oak forests of northern Alabama showed that height growth of white oak was related to slope position and total length of slope. For mixed red oaks, aspect and slope position were the most important factors. Several soil properties were correlated with tree height, but topographic factors were more effective in accounting for height variation. The relation of tree height to topography will enable foresters to select the best oak sites without time-consuming soil analyses.

In black oak stands in southeastern Ohio, topographic features and tree age explains about 75 percent of the variation in tree height. This exceptional precision is due to correlations between topography and many of the soil features that affect oak site quality. Accordingly, topographic features are used for designing soil survey mapping units that can more accurately classify the site quality of land for oaks.

In another study relationships of this type were developed for five important oak species (red, scarlet, black, chestnut, and white oak) on upland sites in the Ridge and Valley region of northeastern West Virginia and western Maryland. Stand age, aspect, slope position, thickness of the A + B horizons, and pH of the A_2 horizon explained 68 percent of the observed variation in height. In comparison with a previous study in the Mountain region to the west where rainfall was much greater, site index in the Ridge and Valley region was appreciably lower for comparable soil and topographic locations.

Within a four-county area in northeastern Louisiana and southeastern Arkansas, latitude accounted for one-half of the variation in pine site quality encountered on four important forest soils--Loring, Grenada, Calloway, and Henry. Site quality differed between soils but declined northward at a similar rate on all soils. Sufficient data are available to calculate the mean site index for a township or to predict the site index for a point within the township. Results will be used by the Soil Conservation Service to assign pine site quality to these four soils throughout the study area.

Weekly measurements of soil moisture and tree diameter growth in eight sawlog-sized stands in northern Louisiana during 1960 and 1961 showed that the trees generally exhausted soil moisture by about July 15 of each year. After this time diameter growth occurred only after each heavy summer rain. Thinning of dense stands to remove surplus trees and the reduction of other competition will allow more of this limited supply of water to become available to the crop trees, with a resulting increase in growth.

Near the western limits of the natural range of loblolly and shortleaf pines, erratic seed-years and recurrent droughts make their natural regeneration unreliable. A greenhouse experiment to assess planting prospects showed that higher clay content of the soils and repeated droughts inhibited shoot and root development of loblolly and shortleaf pine seedlings. However, shortleaf pine consistently had greater root mass than loblolly for comparable treatments. These findings explain in part why shortleaf pine tends to be more drought resistant than loblolly pine.

Compaction by heavy equipment used in harvesting and cultural operations may affect stand growth. In an exploratory study in southeastern Arkansas, seed germination was not affected by soil type or compaction treatment, but seedlings became established with difficulty on clay soils and on heavily compacted soils of lighter texture. Compaction reduced seedling growth. Tillage reduced seedling growth on light-textured soils, but stimulated it on clay soils. This finding points to the need for further study of forest soil

compaction problems and for working out amelioration treatments as pressures for increased timber production leads to more intensive use of heavy equipment in the forest.

The northern spruce-fir forest characteristically has a thick organic layer on the forest floor because the cold climate retards decay. A Forest Service sponsored project in Finland found that certain species of humus-rotting fungi have a pronounced effect on the nutrient status of the soil. Humus resulting from "white-rot" fungi was found to be more beneficial for plant growth than another type produced by the fungus, Hydnellum ferrugineumy. A third group are fungi which maintain activity at low temperatures and grow under the snow, kept the decomposition process going when other fungi were inactive. These studies show that we need a comprehensive understanding of the interactions of all organisms in the plant community to maximize production for human benefit.

In the Pacific Northwest, red alder is often the first tree species to invade clearcut areas. Comparisons of the soils under pure and mixed stands of alder and conifers showed that total nitrogen, nitrate nitrogen, and acidity were always higher under alder and mixed stands than under conifers. Alder produced more litter than conifers, and the litter contained more nitrogen per unit weight. Thus, red alder contributes to forest soil fertility in much the same way as herbaceous leguminous plants. The beneficial effects of red alder on the forest ecosystem coupled with the rapidly increasing commercial value of its wood assure this species permanent status in forestry of the Pacific Northwest.

Dieback and declining vigor of trees have sometimes been attributed to excesses or deficiencies of minor mineral elements. A PL-480 project in Spain found that the contents of boron, copper, iron, manganese, molybdenum, and zinc in the foliage, flowers, cones, and seeds of Pinus pinaster and Pinus pinea were in general independent of the amounts of these elements available in the soil. Older tissues usually contained lower concentrations than young, rapidly growing parts. Old needles collected at the beginning of winter showed the least variation in mineral element content, while the seed coats differed significantly between the two species. These findings will be useful in further research in tree nutrition.

Foliage analyses of black spruce growing in two northern Minnesota peat bogs showed that both nitrogen and phosphorus were deficient on the poorer sites. Nitrogen and phosphorus fertilizers were applied and growth was increased by either element. Best growth was produced by a combination of the two elements; this treatment quadrupled height growth during the first three seasons following fertilization.

The prospect of rapid returns on investments in growing cottonwood makes plantation fertilization a distinct possibility on appropriate sites. Laboratory experiments in Mississippi determined that optimum nutrient levels for seedling growth under experimental sand culture conditions were 100 parts per million (ppm) nitrogen; 75 ppm phosphorus, and 100 ppm potassium. Foliage nutrient contents associated with the best growth were 3.5 to 4.5 percent nitrogen, 0.5 to 0.7 percent phosphorus, and 3.0 to 4.0 percent potassium. Nutrient deficiency symptoms for these elements were similar to those of most agronomic crops.

Fertilization is one very promi sing way of increasing wood production on the limited acreage of forest land. In Louisiana, annual volume growth of slash pine was 170 cubic feet per acre after heavy thinning, only 111 cubic feet per acre when heavily thinned stands were cultivated, and ranged from 146 to 196 cubic feet per acre when thinned and cultivated stands were fertilized at various rates. Trees in heavily thinned, cultivated, and fertilized stands grew nearly 0.5 inch annually in diameter at breast height. Diameter growth of cultivated trees without fertilization was much less. Similar but less pronounced responses to thinning, cultivation, and fertilization were obtained with longleaf pine.

Scattered throughout the loblolly pine region in Arkansas and Louisiana are many flat to slightly depressed places which have slow surface and internal soil drainage. These wetland sites, locally termed "pin oak flats," are occupied mainly by low grade hardwoods. Recent research indicates that a drainage system designed to remove surface water in combination with hardwood removal is an effective and cheap method of converting these sites to pine. After 10 years of study, an inventory of trees on the treated areas showed a stocking level of 250 loblolly pine trees per acre which averaged more than 3 feet per year in height growth. The total cost of conversion, which includes ditch construction and maintenance, cull tree deadening, and planting, was $19.47 per acre. These results show that site quality on poorly drained flats can be improved tremendously by surface drainage.

B. Artificial Regeneration

1. Seed production and handling. The increasing interest in management for seed production makes urgent the need for more efficient seed production and handling through all the steps from the parent tree to the planting site. In the South a study was made to determine reasons for difference in cone and seed yields between longleaf trees in a given stand. Inherent ability to flower, varied between individual trees. Some trees averaged less than 100 flowers per year, compared to more than 500 per year for the heaviest flowering trees. Ability to flower, however, was influenced by fertilizer treatments and rain. The best combination of conditions was heavy spring and summer rain before flowering and heavy annual fertilization. These findings have immediate application in selection of trees and subsequent cultural treatments to increase seed production.

For many years the accepted method of stimulating germination of dormant southern pine seed has been cold, moist stratification for 30 to 60 days. This method is laborious, time consuming, and in some cases results in heating or molding damages to seed. At Alexandria, Louisiana, research has shown that soaking seed in cold, aerated water for 28 days will stimulate germination as well as the conventional method. This new method is easy, and eliminates the chance of heating and molding during stratification. This technique reduces material costs in stratification and should reduce handling by 50 percent.

Normally, placement of such small seed as that of sweetgum should be done so as to take advantage of the microenvironment factors of moisture, temperature, and light. Research at the Eastern Tree Seed Laboratory in Mississippi showed that cold, moist stratification essentially removes the light requirement. Total germination was above 99 percent for stratified and unstratified seeds with continuous light compared to 99 percent for stratified and only 37 percent for unstratified with no light.

Further research on germination of sweetgum seed shows the possibility of replacing the 28-day period of cold moist stratification with a 12-hour treatment of gibberellic acid. Almost 87 percent of unstratified sweetgum seed treated with aqueous solution of gibberellic acid germinated within 28 days compared to only 13 percent of the water treated seeds during the same period. These findings provide considerable flexibility in devising more effective direct seeding procedures.

Spruce pine, a minor southern pine species, is economically important for pulpwood and sawtimber in limited but highly productive areas of the Coastal Plain from South Carolina to Louisiana. Seed studies--the first for this species--showed that (1) cones containing good quality seed can be collected in late October when their specific gravity drops to 0.89, (2) numbers of cones per bushel average about 1,900 with seed yields from 0.1 to 1 pound, (3) sound seeds per pound ranged from 40,000 to 52,000, and averaged 46,000 seed at 10 percent moisture content, and (4) although more difficult to store than seed of other southern pines, viability of spruce pine can be maintained with only negligible loss for 1 year if seed are kept at approximately 6 percent moisture content at near 0 F. This information contributes substantially to guidelines for better management of this timber species.

2. Nursery practices, seeding and planting. One of the most important factors in producing high-quality planting stock is nursery seedbed density. Nursery seedbed density of 3-0 green ash, which ranged from 4 to 36 trees per square foot at Carlos Avery Nursery, Forest Lake, Minnesota, had a marked effect on stem caliper, height, fresh weight, and percent and amount of plantable stock. The highest number of good-quality trees was produced at a density of 12.5 trees per square foot. In Georgia, a similar study showed that most efficient production of sweetgum planting stock resulted when seedbed density was between 15 and 25 seedlings per square foot.

Planted hardwood seedlings are very sensitive to competition of other plants. Herbicides offer one of the best possibilities. In an old field in east central Iowa, a plantation of four hardwood species on a silt loam soil planted to 1-0 stock, 4 pounds of active atrazine or simazine controlled weeds effectively without injuring the trees. Chemical weed control was better on plowed and disked ground than on unprepared ground. Yellow-poplar and white ash grew faster on prepared ground. Black walnut and red oak did not respond to ground preparation treatments. These findings are the basis for guides to develop a cheaper method of establishing hardwood plantations.

Accelerating demand for hardwoods in the Southeast has stimulated interest in planting the more valuable species. Yellow-poplar, cherrybark oak, Shumard oak, swamp chestnut oak, and loblolly pine were planted on a bottomland site. After 11 years, survival by species was 32, 33, 54, 75, and 43 percent, respectively. Volunteers of desirable species were more abundant and larger than the planted hardwoods, but not the planted pine. A single preplanting site preparation treatment may be adequate for loblolly pine but not for most hardwood plantings. Several cultivations or cleanings after planting probably will be necessary for both pine and

hardwoods. In many cases natural reproduction of desirable species should be favored.

The use of coatings to retard transpiration has always seemed to have possibilities of improving the survival of seedlings planted in arid localities, such as the American Southwest. A PL-480 project in Israel made a thorough study of the use of anti-transpirants. Xeromorphic plants, such as Aleppo pine seedlings, do not lose significant quantities of water once the soil in the root zone is dry; consequently, anti-transpirants would have little effect on plant water loss and survival. Studies of the effect of moisture stress at the cellular level showed that extensive and prolonged loss of water from the tissues resulted in changes in biochemical processes associated with photosynthesis, and in submicroscopic structure of the cell. These findings suggest that anti-transpirants are not promising for increasing seedling survival in arid areas.

Large areas of commercial spruce-fir forests in western Colorado have been damaged or destroyed by spruce bark beetles. To return those areas to the fully forested condition will require a successful artificial regeneration program. Several related field studies of seeding and planting Englemann spruce and lodgepole pine showed that: (1) shading increased survival of planted spruce but planted pine survived as well in the open as under shade, (2) shading reduced the incidence of snow mold, (3) new growth of planted spruce is extremely sensitive to frost but that planted pines are not injured by frost, and (4) pocket gophers can destroy established plantations. Seeding experiments showed that: (1) seedlings will not survive the winter if germination occurs late in the growing season, (2) time of germination of spring-sown seed is determined mainly by summer precipitation, (3) a substantial portion of sown seeds may remain dormant for one year, (4) most seedling mortality is caused by frost heaving, mice, and damping-off fungi, (5) sawdust mulch improves germination and survival, and (6) shade increases survival. These studies provide some valuable leads to more fundamental investigations of the physiological response to environment of spruce and fir seedlings. They also demonstrate that considerable additional information is needed before direct seeding can be recommended as a means of artificially establishing either spruce or lodgepole pine.

Black cherry is one of the most valuable timber trees in the U. S. but with natural seeding it constitutes only a minor component of hardwood stands, even in western Pennsylvania where it is most abundant. Direct seeding offers a method of increasing substantially the amount of cherry in new

stands. A study of direct seeding in western Pennsylvania showed that germination was as good on unprepared seedbeds as on scarified and exposed mineral soil, in contrast to seedbed requirements of conifers and other light-seeded species. A burned seedbed, with fuel added, increased early height growth somewhat, but fuel could not be added under practical conditions. Rodents took some seed but birds were not a problem. Rodents and cutworms clipped some seedlings but major damage was done by deer. In many localities in western Pennsylvania and New York, deer preclude establishment of cherry. Thus, direct seeding is a good way to plant cherry but the plantings must be protected from deer.

Knowledge of the best environment for seed germination is a prerequisite to successful direct seeding. The best of several treatments for aiding germination of Nuttall oak acorns, under simulated field conditions of Stoneville, Mississippi, was sowing 1 inch below the soil surface under litter in partial shade. Germination was better when supplemental water was applied; however, the most important factor was depth of sowing. These conditions can probably be met in the woods through site preparation and manipulation of the existing stand. These results will be used by researchers and planters in determining the kind of site and stand treatments needed to improve regeneration of hardwood forests.

In recent years, the increased use of sweetgum in the South has created a need for artificial regeneration of the species. In a recent study to assess the influence of sowing depth on sweetgum regeneration, best results were obtained when seed were sown at depths of 1/4 to 1/8 inch. Any depth below 1/2 inch was detrimental to seedling establishment although, under favorable conditions, seed germinated and became established when planted as deep as 1-1/2 inches in silt loam. Seed sown on the surface did not perform as well as did those with a shallow soil cover.

Successful regeneration of western larch on cutover or burned-over areas may require artificial means when an adequate natural seed supply is not present. Results of a spot seeding study in northern Montana showed that the effects of insolation, the chief cause of seedling death, was greatest on seedlings less than 3 months old on west and south facing slopes. Germination and survival were best when seeds that had been stratified 30 days at 35°F. were sown on north facing slopes immediately after snowmelt. Seed soaked in hydrogen peroxide and seed with no pretreatment germinated poorly. Seedling survival was low on south and west facing slopes regardless of seed pretreatment. Drought, insolation, frost heaving, and fungi caused most of the seedling mortality; loss to animals was slight. Coating seed with chemical repellent was only partially successful; use of screens

to protect seed spots from animals was successful but is too expensive for use on regeneration projects. Knowledge of the relative importance of several mortality factors provides direction for future studies to improve regeneration success.

Competing vegetation must be removed or deadened to obtain successful establishment of planted ponderosa pines in the Southwest. Six herbicides--dalapon, an ester of dalapon, simazine, amitrole, amitrole-T, and ammonium thiocyanate--were compared on perennial grasses in Arizona. All except ammonium thiocyanate killed the grass. Dalapon, however, was the cheapest. Applied at a rate of 5 pounds of active ingredient per acre, dalapon killed 86 to 94 percent of the grass at about one-third the cost of scalping. Based on the current planting program in the Southwest, use of dalapon will save about $45,000 annually.

On about one-half of the lower Piedmont of Georgia offsite hardwoods are replacing the old-field loblolly pine stands. Prescribed burning may be an economical way for temporarily suppressing the hardwoods so that the more valuable pine can be established on such sites. In this study it was found that summer burns top-killed 80, 63, and 33 percent of the hardwoods in the 1-, 2-, and 3-inch d.b.h. class, respectively, as against 73, 29, and 12 percent by winter fires. Of course, the hardwoods sprouted again, but 73 percent of the milacre quadrats on summer burned plots supported free-growing loblolly pine seedlings 2 years after burning as against 57 percent on winter burned plots and 34 percent on unburned plots. Soil erosion on the duff-mull sites was negligible. These findings should be compared with results from mechanical site preparation and direct seeding, especially with reference to costs which may favor prescribed burning and natural seeding by as much as $50.00 per acre.

Prescribed burning to establish and maintain pine in the upper Piedmont presents somewhat different problems from those of the lower Piedmont because fuels are more compact and the slopes longer and steeper, thus making burning more difficult. Furthermore, the shortleaf pine is the major species of the upper Piedmont and is a poorer seed producer than loblolly pine which predominates in the lower Piedmont. In the Southeast results of two kinds of growing season burns, spring and summer, and no burning were compared. The spring fires top-killed twice as many hardwoods through the 3-inch diameter class as did summer fires. Loblolly pine direct-seeded on any type of burn provided, in the first year, 53 percent milacre quadrat stocking as against 18 percent on unburned plots. Use of fire for hardwood control and site preparation will greatly reduce the cost of reestablishing pine from that of mechanical methods.

C. Natural Regeneration

Although the trend to even-aged management is due, in part, to the ease of obtaining reproduction of the less tolerant species, comparatively little data is available on the nature and timing of regeneration that appears after even-aged harvest cutting in eastern hardwoods. A study in West Virginia showed the quantity, origin, and species composition of reproduction present 3 years after seed-tree cutting in Appalachian hardwoods. Reproduction of desirable species was abundant and well-distributed, and was composed of a large proportion of seedling-origin stems. Species composition was better and abundance greater on sites of good quality. These results show that reproduction established after seed-tree cutting meets all the expectations of even-aged management.

Complete clearcutting has seldom been attempted in northern hardwoods of New England. A few small, preliminary trials suggested that this cutting method might not produce satisfactory results. However, 30-year records of an experimental 22-acre clearcutting in old-growth northern hardwoods indicated that good results can be expected. Shortly after cutting the stand contained a high proportion of brush, weed trees, and sprouts, but by age 25 valuable intolerant and intermediate species (e. g. paper birch, yellow birch, white ash, red maple) dominated the stand. The stand currently exhibits the stocking, quality, and growth rate required for valuable products. Results show that complete clearcutting can be a highly successful cutting method in northern hardwood stands.

Knowledge of the development of regeneration under a wide range of overstories is helpful in deciding how heavily to cut sugar maple stands for multiple-use objectives. In North Central United States, studies of regeneration 2, 5, and 10 years after cutting mature and overmature sugar maple stands to several residual densities show that (1) sugar maple is still the predominant species under all stand densities, (2) nearly all regeneration reaching larger size classes became established before cutting, and (3) heavier cuttings--30, 50, and 70 square feet--are more rapidly making up deficits in sapling and pole sized classes than the lightest cutting of 90 square feet.

Harvest cuttings in the Piedmont and Coastal Plain of the Northeast often failed to provide good stocking of yellow-poplar in succeeding stands. In this study of 17 areas, different treatments were tried to determine their effects on the establishment and growth of yellow-poplar reproduction.

Results emphasize the importance of fairly large overstory openings (preferably 1 acre or more) and of not leaving scattered trees, even for seed. Scattered trees interfere with yellow-poplar reproduction and are not needed for seed since yellow-poplar seedlings start from seed stored in the forest floor. Reductions in understories through herbicide spraying, burning, or disking are also highly important in obtaining satisfactory establishment and growth of yellow-poplar reproduction. Even though seedbed treatments increased the catch of first-year seedlings by 2 to 28 times, they are necessary only in areas borderline because of deep litter, scant seed supply, or dense herbaceous growth.

The prolific sprouting habit and rapid growth of the sprouts are important features of redwood. A study in California showed that about half the stems in young-growth redwood stands originate from sprouts. Although the number of sprouts per stump was not related to the parent tree's size or age, more stumps of smaller and younger redwoods sprouted than stumps of larger and older trees. And smaller stumps produced the largest sprouts during the first decade after logging. Almost all stumps that produced sprouts, do so within 3 years. A stump supporting live sprouts can be expected to continue sprouting for several years. This ability to sprout can be used to advantage in regenerating redwood stands.

Natural regeneration in newly logged area in southeast Alaska is not likely to be a serious problem. Eight years after clearcutting a 700-acre tract on the Maybeso Experimental Forest, natural regeneration met stocking standards, with 83 percent of 4-milacre plots stocked with at least one seedling. Seed was abundant throughout the cutover. Several problem situations were identified, associated with seedbed conditions rather than lack of seed. Problem situations were dense brush on alluvial soil, alder competition on highly disturbed ground, and landslide scars on steep slopes. In some cases tree seedlings became established in such profusion that thinning appears desirable for optimum stand development.

The seeds of swamp tupelo are heavy and yet are distributed widely from the seed-producing trees. In South Carolina studies of seeding habits of this species, seeds which landed in seed traps lacked the juicy, dark blue-colored flesh of the natural fruits; only the seed remained. What was happening to the fruit? As if nature had ruled it so, each year at the time of peak seed ripeness, huge flocks of migrating robins appeared in the swamp. The birds stayed for many days, gorging themselves on the nutritious fruits. To a lesser extent, bluebirds, cedar waxwings, and blackbirds were also observed feeding on swamp tupelo fruits. Nearly half

of the total seed crop passes through the birds' digestive tracts. This results in a wider, more uniform distribution than would otherwise occur with the heavy tupelo fruits. Thus, robins and other birds seem to be an important factor in the perpetuation of swamp tupelo by aiding its seed distribution. And by favoring this very desirable timber tree, foresters are ensuring an important source of food for migrating robins.

Paper birch is in great demand but the growing stock has decreased drastically in recent years, apparently because harvested stands were not replaced by birch seedling stands. In the past wildfires created the kind of seedbed necessary for paper birch regeneration. A study in Maine showed that as a substitute for wildfires disking or prescribed burning will provide favorable seedbeds, resulting in up to three times as much paper birch stocking as no treatment, and up to six times as many paper birch seedlings per acre five growing seasons after logging. If nearly pure stands of paper birch are desired, a special effort must be made to scarify the soil after logging.

Slash burning in young-growth ponderosa pine stands in California is considered expensive, difficult, and risky. However, results from broadcast burning 17 small clearcuttings which ranged in size from 2 to 46 acres show that broadcast burning is practicable, economical, and possible both in the spring and fall. The success of fall burns depends on the weather. Fall burns generally consume more of the heavy fuels but require heavier manning, hence are more expensive. Spring burns usually are undertaken early during periods of sunny weather between major storms. At least one of the drier periods occurs each year. Because subsequent storms are sure to come, less risk is involved and manning and equipment needs are substantially reduced. The ability to burn during the two seasons broadens the applicability of slash controlled burning as a silvicultural tool. Costs for five different broadcast-burning slash-disposal operations varied between $8 and $61 per acre compared to the bulldozing costs of $30 to $50 per acre.

In the lower Mississippi Valley, eastern cottonwood becomes established by seed in early and middle summer on open land created by receding water courses. The seed is highly sensitive to environmental conditions. Studies conducted at the Southern Hardwoods Laboratory showed that the rate and amount of germination, normally high at dispersal, decreased rapidly as moisture stress increased. The highest germination energy of fresh seed occurred at 90°F. when moisture was plentiful. Germination energy decreased as available moisture decreased, stopped when soil moisture was reduced to the melting point. It was also determined that low temperature drastically reduced germination of fresh seed, and that high

temperature, 100°F. reduced germination energy after storage. Such information on germination requirements is essential to effective regeneration measures for the species.

Prescribed fire for the control of brown-spot needle disease in longleaf seedling stands may do more damage than good if unsuitable methods are used to appraise the extent of brown-spot infection. In an 80-acre area in southwest Alabama, two different methods were used to determine whether a brown-spot burn was needed. The "crop-seedling method," based on selecting the best or "crop" seedling on 100 sample milacres per forty, indicated that the area should not be burned. Brown-spot infection was estimated to be only 20 percent, yet fire would kill or severely damage 46 percent of the seedlings. In contrast, the "mean-seedling method" (100 mechanically selected seedlings per forty, without regard to quality) indicated that a burn was needed. In this case, brown-spot infection was estimated at 40 percent with only 34 percent expected fire damage. But on the basis of the "crop-seedling method" the area was not burned and a year later the crop seedlings were growing well. Appraisal by the "crop-seedling method" will benefit foresters managing longleaf pine by improving their techniques of prescribed burning to control brown-spot needle disease.

D. Multiple-Use Silviculture

Subalpine fir is a wide ranging conifer in mountain regions of Northwestern North America. It is a major component of the vegetation in wilderness and scenic areas, and in high elevation watersheds. The status of subalpine fir in plant succession in the Cascade Range was found to be far different from that in Rocky Mountain spruce-fir forests. In the Cascades, it regenerates only following disturbance and subject to gradual elimination by more tolerant associates. Hence, silvicultural prescriptions for management of subalpine fir in the Rockies cannot be applied in the Cascades. On some other sites, such as recent lava flows and talus, it invades and remains as a localized climax species. Subalpine fir is also an important pioneer tree near timberline. Its ability to enlarge original colonies by rooting of low branches partially accounts for its success on these adverse sites. By providing cover on these and fire-devastated tracts, subalpine fir is a distinct asset for watershed protection and landscape rehabilitation, and should be favored on areas where damage by balsam wooly aphid is not a serious problem.

The effects of livestock browsing on pine seedlings has never been adequately resolved. Doubts led to a 5-year study of browsing effects on the establishment, survival, and growth of longleaf pine seedlings on the Escambia Experimental Forest in southwest Alabama. Overall, 23 percent of the seedlings were killed and diameter growth of survivors was reduced by 13 percent. On browsed plots milacre stocking dropped from 78 to 48 percent, and seedling numbers from 3,206 to 1,014 per acre. On protected plots the decline was from 77 to 61 percent, and seedlings from 4,014 to 2,206 per acre. Although one cow per 40 acres yearlong was the estimated carrying capacity of the range, this study indicated that in southwest Alabama, one cow grazing yearlong on 50 acres may be too much.

The importance of soil moisture to tree growth has long been recognized but irrigation has not been feasible because of high costs. However, if irrigation also enhances other values, it might be profitable. In the Mississippi Delta, duck hunters construct shallow water impoundments in forested areas to support ducks in the winter. In a study at Stoneville, Mississippi, it was found that these impoundments can be regulated to produce large increases in tree growth. Water impounded up to 3 feet deep in the winter and released by July 1 increased tree diameter growth by 50 percent. It also made the area available for duck feeding. And it is a way to prevent reduced growth, dieback, and mortality on these areas in drought years. Thus, the added benefit to duck hunting makes irrigation a real possibility in the intensive culture of high value hardwoods.

Information on the nature and causes of sprouting was needed to assist in the development of appropriate silvicultural methods for both timber and wildlife purposes. A study of sprout development following a range of cutting intensities from clearcutting to light partial cutting revealed that: (1) red maple was a much more prolific sprouter than sugar maple or paper birch, while yellow birch was essentially a non-sprouter; (2) small stumps sprouted more vigorously than large stumps; (3) stumps from vigorous red maple trees produced more--but shorter--sprouts than stumps from less vigorous trees; (4) residual basal area had little effect upon sprout numbers or heights. The results indicate that sprouts can be induced or restricted by prescribed cutting practices, thus permitting alternative management objectives.

E. Stand Improvement

At present, stem injection of herbicides is the most popular control method for eliminating weed trees but efficiency can be increased. Results from a study in Michigan that can reduce costs include the following: (1) Only about one-fourth the quantity of the amine salt is required to kill pole-sized northern red oak compared to ester formulation in spaced stem injections; (2) only about one-half the quantity of the amine salt is required per tree during the growing season compared to the dormant season; (3) spaced injections may be made at any height along the stem, and (4) hardwoods with large spreading crowns and forked stems can be killed more easily by edge to edge injections completely around the stem with low quantities of 2,4,5-T than by spaced injection.

The shortrun future of the black walnut industry lies in trees now living and the action taken to speed their growth without sacrificing quality. After 4 years, pole-size black walnut trees in southern Indiana, given complete crown release had grown twice as fast as trees not released, 0.65 inches vs. 0.35 inches at breast height. Thus, by careful tending, more of the walnut trees found per acre can be brought to harvest size on good sites. Demonstration of this response to release is expected to have an impact on landowners' management practices for walnut, and if practiced should have an appreciable impact on the walnut supply for industry.

White oak represents a dominant high-value species in forests of the Central Hardwoods region, but unless the growth of these trees is speeded up, the rotation age will be quite long. Crown release and pruning of pole-size trees can increase the amount and quality of white oak and greatly shorten the rotation. In southern Illinois crown release increased diameter growth over a 10-year period 1.5 to 4 times; codominant trees grew 2.0-2.3 inches during that period. Released trees became a permanent component of the stand overstory. The correct application of this practice can easily make 100 percent difference in yield and quality during the next 20- to 30-year period.

Persistent epicormic branches reduce the quality of hardwood lumber and veneer. Epicormic branches have been thought to originate almost entirely from dormant buds. At Athens, Georgia, it has been found that a few species also produce many adventitious buds, which can be newly formed in the cambial tissue at any time, usually as the result of small, localized

injuries. On yellow-poplar, sweetgum, green ash, and red maple, the epicormic branches originating from adventitious buds are uncommon and die soon after formation. Unlike the branches from dormant buds, those from adventitious buds may be of little consequence in lumber defects in these four species. On water and white oak, however, 30 percent or more of the epicormic branches appeared to be of adventitious bud origin. On these two species, the adventitious buds may give rise to long-lived epicormic branches which can be a significant factor in lumber degrade.

Many thick clumps of sweetgum reproduction, which are thought to originate from seed, are clones that have originated entirely from root suckers. In the Georgia Piedmont observations of lateral root segments reveal numerous suppressed buds embedded in the bark with vascular traces extending either to the xylem of the primary root or to a point of previous root injury. Clusters of adventitious buds are often found embedded in the bark in swellings associated with aborted lateral roots. The exposure of lateral roots to light resulted in the immediate release of numerous suppressed buds all along their surface. Complete girdling of exposed lateral roots resulted in released buds on the side of the girdle away from the parent tree, indicating that some type of inhibition was removed. Observations confirmed origin of suckers from previously formed suppressed buds. Thus, root suckering increases the assurance of stand regeneration and also explains the sprouting of root segments of sweetgum, which is very useful in genetic improvement of the species.

Rhododendron thickets occupy several million acres of Southern Appalachian timberland and seriously impede reforestation efforts. A recent study of a number of these thickets on the Bent Creek Experimental Forest indicated that they are mostly even-aged and their average age ranges from 49 to 61 years. The consistency of age within a thicket and among thickets indicates that they are rather static communities and, at least as long as they are undisturbed, are not spreading.

Windfall is an important cause of mortality after initial cuttings in mature stands of spruce fir and lodgepole pine in the Rocky Mountains. It is especially serious along the margins of clearcuttings. Guidelines have been developed from this study to minimize windfall when locating clearcut boundaries. Cutting unit boundaries should not be located to the east or south of saddles in ridges, or on ridgetops. Leeward boundaries on

shallow soil should be avoided. Cutting units should be as large as conditions permit to minimize perimeter and make boundary location more flexible. Cutting unit boundaries should not have windcatching indentations, or be parallel to prevailing wind direction. The forest manager can now identify situations and conditions where windfall risks are above and below average.

A wood property associated with thinning response is specific gravity, which increases pulp yields and strength of the wood for lumber. Increment core analysis of larch crop trees 15 years after thinning revealed that thinning increased their specific gravity over that of comparable trees in unthinned stands. The increase in specific gravity was related to intensity of competition--specific gravity increased from 0.514 to 0.563 with initial basal area of 44 square feet, and from 0.501 to 0.518 with 135 square feet. These results demonstrate that thinning not only increases diameter and basal area growth of larch, but also improves the wood properties associated with specific gravity.

Approximately 1.3 million acres, or 81 percent of the total redwood type of northwestern California consists of high production second-growth stands. Yields of 100 year old stands are estimated to range up to 350,000 board feet per acre on the best sites making this the most productive timber type in the United States. Regionwide, the oldest and most accessible second-growth stands are stocked the best. Thirty- to 50-year-old stands are those with the most variable, perhaps slightly understocked condition. In the oldest of the second-growth stands, harvesting has slowly increased in volume since 1946. A few commercial thinning examples on both small and large ownerships indicate the current effort to upgrade quality of the reserved stands. Vigorous response to increased growing space by this species should result in increased future production.

F. Animal Damage

Deer browsing of Douglas-fir seedlings causes tremendous financial losses, not only by direct injury and death of seedlings, but also by retarding growth and delaying merchantability. This has stimulated fundamental research on why deer prefer Douglas-fir seedlings to other vegetation. Building on knowledge and techniques developed for domestic livestock, investigators supported by a Forest Service research grant at the University of California are studying the digestibility of Douglas-fir to deer. High levels of essential

oil distilled from Douglas-fir needles decreased deer rumen microbial action on alfalfa below that on alfalfa alone, indicating poor digestibility, while low levels stimulated rumen microbial activity. Of the three components in the essential oil, monoterpene hydrocarbons and sesquiterpenes promoted digestion while oxygenated monoterpenes inhibited digestion. These findings point to two possibilities: first, the development of more effective chemical repellents using chemicals that inhibit digestion; and, second, genetic selection and breeding of strains of trees containing higher concentrations of digestion-inhibiting compounds. This research also illustrates the necessity for thorough study of fundamental processes to solve stubborn problems.

Most effective adhesion of TMTD rabbit repellent to Douglas-fir seedlings is obtained when applied during warm, dry weather, but the contrasting cool and moist weather requirements for successful outplanting frequently necessitates holding treated seedlings in cold storage. A study near Olympia, Washington, showed that growth, survival, and repellency of treated seedlings were affected adversely by storage before outplanting. Therefore, Douglas-fir seedlings should be sprayed with TMTD repellent just before outplanting. If conditions for outplanting become unfavorable, seedlings should be left in nursery beds, especially if it is early in the season before they are completely dormant.

Because of the shortcomings of chemical repellents to hares and rabbits, better control measures are needed. Silvicultural control may be possible but development of such methods requires knowledge about the habitat requirements of the animal, its preference for different foods, and factors affecting feeding habits. This line of research was started with a study of hares' reaction to a diet of catsear plant, a preferred food, on a tract cleared of Douglas-fir in Washington. The study showed that the animals preferred flowers and flower buds over the leaves of the plant. The study also showed that the level of sugar in the different parts of the plant might be responsible for the observed order of preference. Plants rich in sugars, therefore, might be used to divert these animals from less-sweet planted seedlings.

Mountain beaver clip stems and branches of many woody plants in the Tillamook Burn, Oregon, where repeated wildfires have killed thousands of acres of timber and brush. The exact role of this small burrowing animal as a modifier of habitat for tree growth and wildlife production was investigated in cooperation with the Oregon State Game Commission. Among 12 plant species studied, vine maple, red huckleberry (whortleberry), and red alder were clipped most frequently. Results suggest that

mountain beaver can produce and maintain sizable openings in brush stands. Composition of woody plants can also be controlled to some extent through selective clipping by these animals. This knowledge is another step toward a better understanding of the complex plant-animal relationships in the ecology of an area in Oregon of vital concern to foresters and wildlife biologists alike.

Foresters and ecologists have been concerned over the possible destructive role of small mammals such as mice, voles, and shrews, in reforestation after clearcutting of western hemlock-Sitka spruce timber stands in southeast Alaska. A 9-year census study showed that the white-footed mouse population was consistently lower on the cutover land than in uncut timber. Vole and shrew populations increased somewhat on the cutting in some years, but remained low. Populations were highest 3 years after logging, and thereafter declined, with some variation by species. Adequate natural conifer regeneration of approximately 550 Sitka spruce and western hemlock seedlings per acre became established on the cutover plot from seedfall and residual seedlings despite the presence of small mammals. These results are encouraging because they indicate that the natural ecology on cutover timberland in southeast Alaska need not be further disrupted by attempts to control the small mammal population present.

G. Growth Requirements

Under natural conditions pines, and many other forest trees, grow best in partnership with fungi through formation of mycorrhizal structures on the roots. Some fungi are highly specialized, developing only under certain conditions or on specific media. A PL-480 project in Poland resulted in a reliable method of identifying mycorrhizal fungi that ordinarily do not fruit in culture. Mycelia cultured from identified sporophores and from mycorrhizae were grown under identical laboratory conditions. By comparing developmental and morphological characters of fungi isolated from naturally-occurring mycorrhizae were identified. On the basis of its morphological and physiological characteristics the mycelium isolated from a mycorrhiza was assigned to one of ten groups. Seven of these groups belonged in distinct families. Several isolates were further identified to genus, and some to species. This method will facilitate research on this important factor in tree growth.

Over 51 million Douglas-fir seedlings were produced in the Pacific Northwest in 1967. Fertilization is necessary for optimum growth of these seedlings both in the nursery and on many planting sites. To develop preliminary standards of fertilizer requirements, concentration of mineral elements essential to plant growth were analyzed in foliage of seedlings growing on excellent forest sites. These concentrations were then compared to those of Douglas-fir seedlings growing in private, State, and Federal, nurseries in the Pacific Northwest. The comparisons pinpointed possible changes needed in present fertilizer use. Improved fertilization practices will insure optimum growth in the nursery and increase success of reforestation efforts.

Experience has shown that proper timing of seedling lifting in the nursery and planting in the forest markedly influence reforestation success. Research recently completed has shown that roots of Douglas-fir seedlings grown in a nursery were observed to grow most rapidly in early spring before top growth started and again late in the summer after top growth had slowed down. Height growth stopped in early summer, but stem diameter growth continued till November. Maximum concentrations of carbohydrates, the most important food reserves, were not reached until midwinter. They dropped off again as root growth accelerated in the spring. Fall lifting should be done as late as possible to insure use of dormant seedlings containing high food reserves. Spring lifting and planting should precede start of top growth by at least 3 or 4 weeks so that seedlings are dormant when lifted in their major burst of root growth will be expended in the forest rather than in the nursery bed.

Food reserves within Douglas-fir seedlings in the Pacific Northwest peak in concentration during late fall and winter. Though relatively low, measured wintertime photosynthesis rates appear of sufficient magnitude to account for the increase in food reserves. Early and long lasting snow cover may limit reserve buildup and thus prevent seedlings from attaining maximum potential for growth, which is partially fueled from stored foods. New root growth, on the other hand, could be limited theoretically by any of several physiological processes. Defoliation experiments showed that root growth of fall-lifted seedlings is quantitatively related to the net amount of food synthesized by seedling tops. Thus, for most rapid establishment on favorable sites, forest nurseries should produce large-crowned Douglas-fir seedlings.

Newly planted Douglas-fir seedlings grow slower than seedlings in place. Quantity of internal food reserves available in older foliage may directly affect a field-planted seedling's vigor and early growth. We have learned that both mineral and carbohydrate reserves move from old to developing Douglas-fir shoots during spring growth. In the seedlings studied, about 80 percent of the nitrogen gained by new shoots by early summer apparently came from adjacent older shoots. This information supports the concept and stresses the importance of maximizing internal mineral and food reserves through optimum fertilization before a seedling is shipped from the nursery to the field.

In attempting to determine the nutrient requirements of trees, it is important to know whether a mineral element is actively absorbed by the tree, which would suggest absorption limited by requirements, or whether it is passively absorbed, which would mean absorption limited mainly by supply. In a study conducted jointly by the Forest Service and the University of Georgia, the rates of transpiration and oxygen tension around the roots of sand-culture grown slash pine seedlings (Pinus elliottii Engelm. var. elliottii) were varied and the corresponding uptake and translocation of calcium measured. The uptake was divisible into two components: (a) an accumulation by the roots and (b) a passage through the root to the shoot. Both (a) and (b) were unaffected by changes in oxygen tension. However, while (a) was unaffected by the amount of water transpired (b) was linearly related to it. The linear relationship between the amount of water transpired and the transport of calcium to the shoot indicates that the process of calcium accumulation is transpiration-dependent in slash pine. The lack of inhibition of calcium accumulation by the roots or shoots by increased oxygen tension is additional support for a predominately passive accumulation of calcium by slash pine.

A well-developed and deeply penetrating root system helps ponderosa pine seedlings resist two major causes of mortality--drought and frost heaving. A study conducted by Forest Service scientists in the phytotron at the California Institute of Technology showed that root growth responded more to soil temperature, while top growth responded more to air temperature; however, both were significantly influenced by the interaction of air and soil temperature. Seedlings from three widely separated seed sources responded similarly to the temperature regimes, but source had a pronounced effect on final seedling size--seedlings of California source were largest, Arizona intermediate, and South Dakota smallest. This information will help to write guidelines for selection of sites for forest tree nurseries and outplantings and for site preparation measures that will provide the best environment for seedlings.

The mechanisms of drought resistance were studied by scientists in Israel supported by a PL-480 grant. At the outset it was learned that these mechanisms are complex. For example, a species may have a needle cuticle that effectively retards moisture loss but roots that are less resistant to soil moisture stress. Nevertheless, a combination of properties permitted relative rating of seven pine species for drought resistance. Mediterranean pines were more resistant than American pines. In ascending order of drought resistance, the American pines were as follows: Pinus radiata, P. ponderosa, P. coulteri, and P. jeffreyi. The natural distribution of these species and plantation success outside their natural range were correlated fairly well with this rating. Metabolic studies were inconclusive but showed that respiration in needles was more stable and total protein and ribonucleic acid were higher in P. halepensis, the most drought resistant species, than in P. radiata, the least resistant species. This information indicates that American pines probably would not fare well in the Middle East but that Mediterranean pines might permit afforestation of some presently treeless areas in this country.

Water content of leaves is of practical importance, since it is often used as an index of drought severity. Through a pot study of Douglas-fir, grand fir, ponderosa pine, sugar pine and incense cedar at Roseburg, Oregon, it was determined that temporary stress occurs, even under conditions of low soil-moisture tension, in extremely hot or cold weather. The very low moisture content known to occur in early spring may not be caused by water stress as was previously believed, but may be due to other causes, such as a dry-matter buildup while water content remains constant. The late-spring succulence of mature conifer foliage, heretofore associated with bud break and flushing, can actually occur as much as a month later. The temperature threshold is probably lower for bud break and flushing than for the rise in foliage succulence. A drop in moisture content, similar to that occurring in the fall with the onset of cooler weather, was found in hot weather in greenhouse plants that by July had completed a full summer's growth cycle. Thus, some seasonal changes in moisture content may be caused directly by environmental changes, whereas others are only indirectly tied to changes in the environment and are probably more closely allied with metabolic or growth changes within the plant.

Different types of swamps may impose rigid limitations on seed selection for tupelo regeneration. One-year-old seedlings of swamp tupelo and water tupelo from three different types of swamps were grown for one growing season at the Santee Experimental Forest in South Carolina under six

artificially imposed water treatments. Height growth and dry weight varied significantly between some seed sources for each species. Both height growth and dry weight were lower under intermittent and continuous flooding than under continuous saturation. Thus, swamp tupelo and water tupelo seedlings exhibit physiographic seed source variation under artificially imposed water regimes. These results indicate that seed for tupelo gum regeneration should be collected within the swamp site in which it is to be planted.

The contribution of roots to growth of trees has not been investigated to any great extent, yet root differences and behavior might have great effects on growth of the aerial portions, especially if root differences are inherent. A series of studies at Gulfport, Mississippi, examined the root-crown relationships among species of southern pines and among geographic sources of shortleaf pines. Using trees where roots and tops were interchanged by grafting between slash, loblolly, and shortleaf pines, scions grafted on root-stocks of faster growing species averaged little or no more height growth than on their own roots. Scions grafted on rootstocks of slower growing species averaged less growth than on their own roots. In a similar study with shortleaf pine, seven geographic sources were used and tops and roots interchanged among them. After 3 years roots had contributed little to geographic variation in height. Variation in height appears to be primarily a function of the above ground portion of the tree.

Although root grafting between trees of the same species is quite common, little is known about the physiological and pathological relationships involved, especially between living stumps and donor trees, or the extent of intra-specific root-grafting within certain species. Results from study of loblolly pine stands near Durham, North Carolina, indicate from 5 to 25 percent of the trees are root grafted to neighboring trees. These grafts serve as translocation avenues for water and minerals at the rate of 1 to 3 feet per hour as measured by injections of radioactive phosphorus, P-32. In the case of root-grafted stumps, the movement seemed to be continuous from stump to donor tree. Sharp reductions in P-32 absorption when clouds blocked the sun indicate the entire absorptive system of a tree is sensitive to comparatively minor changes in solar energy. Diurnal fluctuations also suggest that many grafts function only during times of high water stress. As to the direct physical relation between grafted stumps and the host tree, the data indicated that growth of the donor tree was not significantly affected.

At our pioneer research project on tree physiology at Rhinelander, Wisconsin, processes of wood formation were investigated in 3-year-old Pinus resinosa seedlings from 10 widely separated natural stands in Northeastern United States and Southeastern Canada. Differences among sources were found in terminal elongation and needle size, but no reason for these differences was evident. High temperatures reduced height growth but increased needle elongation; whereas low temperatures increased height growth but reduced needle elongation. This inverse relationship probably was caused by the influence of temperature on the distribution and utilization of assimilates, primarily reserve foods. Eventually such knowledge will help us devise silvicultural systems to produce wood of more uniform properties and more suitable for particular uses.

Man has harvested the forest for centuries and used the wood for many different purposes but we still know very little about how it is formed in the tree. A PL-480 project in Israel investigated the factors controlling the annual rhythm of wood production. In some species, the cambium could be kept active throughout the year by maintaining favorable environmental conditions. Conversely, other species entered a state of dormancy regardless of growth conditions. Temperature constituted a major factor in the control of cambial activity. Under favorable temperature conditions, the cambium remained active even though other visible growth processes had stopped. Photoperiod appeared to exert a direct effect on bud growth and its effect on cambial activity was, therefore, indirect. In desert plants, water stress played a major role in the control of cambial activity. It could not be ascertained whether the effects of water stress on cambial activity were direct, or whether they were mediated through the buds. This information brings us a little nearer the goal of controlling the type of wood formed to serve different uses.

Recent advances in molecular biology permit the conclusion that essentially all phases of plant growth and development are controlled or mediated by two kinds of nucleic acids--the genetic-information-bearing type, DNA, and the protein-synthesis-directing type, RNA. A PL-480 project in Finland developed the knowledge that during the annual morphogenetic cycle of Scotch pine buds, cell number, cell size, nuclear volume, and the content of DNA and RNA fluctuate widely, and that a pattern is just becoming discernible in these fluctuations. For example, male flower primordia contain about three times as much DNA as do spur shoot primordia, but content in both

remains relatively constant from November to April. In contrast, DNA of female primordia seems to increase during the winter. Female primordia also have a much higher RNA to DNA ratio during dormancy than male or spur shoot primordia, but the values converge at time of bud-break. It is likely that in spring a reactivation of nucleoli concomitant with an RNA increases, precedes a DNA increase and that an increased mitotic rate follows. More work is needed to substantiate the sequence of these changes and to establish cause and effect relations. This information expands the basis for our eventual understanding of the processes that control tree growth and development.

RPA 101-APPRAISAL OF SOIL RESOURCES

Site Evaluation and Soil Improvement

Identification of animal life in the soil is prerequisite to learning its habits and determining its role in soil development. During an intensive study of mite populations in the forest leaf litter in Wake County, North Carolina, 1,800 specimens of Phytoseiidae were collected. The collection contained 15 previously unrecorded specimens and three undescribed. These and the 15 previously unrecorded species facilitate future study of their role in soil development.

Acarina, or mites constitutes a large part of the myraid small animals which live in the forest floor. A study in a pine and hardwood stand in North Carolina was made to determine the abundance of certain acarina in three species of decomposing leaves. As the leaves decomposed, there was a succession of species of phytoseeids, ascids, and veigaiids. Nine families of mesostigmata, eight families of trombidiformer, and 41 genera of oribatei were represented in the final collection. Basic knowledge of this kind contributes to the eventual manipulation of the forest floor to maintain or increase the soil fertility.

RPA 102-SOIL STRUCTURE-SOIL, WATER, PLANT RELATIONS

Artificial Regeneration

Soils of southern pine nurseries contain mycorrhizal fungi, which grow on fine roots of seedlings, with a mutual benefit to both seedlings and fungi. However, large numbers of seedlings may not become visibly infected with fungi before they leave the nursery. A study in Louisiana showed that presence of visible mycorrhiza on roots of slash pine seedlings may be as important as seedling grade in determining survival. More mycorrhizal than nonmycorrhizal seedlings survived on a moderate site. An overall increase in survival of about 10 percent would have been achieved if all plants had been mycorrhizal.

Publications - USDA and Cooperative Program

RPA 111 - TIMBER MANAGEMENT

Site Evaluation and Soil Improvement

Bassett, J. R., and Beene, J. T. 1967. Loblolly pine site quality of four loess soils. U. S. Forest Serv. Res. Note SO-68, 6 pp.

Bollen, Walter B., Chen, Chi-Sin, Lu, Kuo C., and Tarrant, Robert F. 1967. Influence of red alder on fertility of a forest soil. Oregon State Univ. Res. Bull. 12, 59 pp., illus.

Bonner, F. T., and Broadfoot, W. M. 1967. Growth response of eastern cottonwood to nutrients in sand culture. U. S. Forest Serv. Res. Note SO-65, 4 pp., illus.

Carmean, W. H. 1967. Soil survey refinements for predicting black oak site quality in southeastern Ohio. Soil Sci. Soc. Amer. Proc. 31: 805-810.

Dean-Guelbenzu, Miguel. 1967. Oligo-elements concentration of floral and foliar parts of forest trees. Final Report, PL-480 Project, E25-FS-15, Spain.

Foil, R. Rodney, and Ralston, C. W. 1967. The establishment and growth of loblolly pine seedlings on compacted soils. Soil Sci. Soc. Amer. Proc. 31(4): 565-568.

Hintikka, Veikko. 1967. The role of soil fungi in the formation of different humus types, especially in raw humus formation in northern forests. Final Report, PL-480 Project, E8-FS-49, Finland.

Moehring, David M. 1967. Converting a pin oak flat to pine. U. S. Forest Serv. Res. Note SO-55, 3 pp., illus.

Moehring, David M., and Ralston, C. W. 1967. Diameter growth of loblolly pine related to available soil moisture and rate of soil moisture loss. Soil Sci. Soc. Amer. Proc. 31: 560-562, illus.

Shoulders, E. 1967. Growth of slash and longleaf pines after cultivation, fertilization, and thinning. U. S. Forest Serv. Res. Note SO-59, 3 pp.

Smalley, G. W. 1967. Soil-site relations of upland oaks in north Alabama--A step in the model-building process. U. S. Forest Serv. Res. Note SO-64, 6 pp., illus.

Stransky, J. J., and Wilson, D. R. 1967. Soil moisture and texture affect root and shoot weights of transplanted pine seedlings. U. S. Forest Serv. Res. Note SO-62, 3 pp.

Watt, Richard F. 1967. Growth of black spruce stands after fertilization treatments based on foliar analysis. Proc. Soc. Amer. For., 1966, pp. 85-88.

Yawney, Harry W., and Trimble, G. R., Jr. 1968. Oak soil-site studies in the Ridge and Valley Region of West Virginia and Maryland. U. S. Forest Serv. Res. Pap. NE-96, 20 pp., illus.

Artificial Regeneration--Seed Production and Handling

Barnett, J. P., and McLemore, B. F. 1967. Study of spruce cone maturity and seed yield. U. S. Forest Serv. Tree Planters' Notes 18(2): 18.

Barnett, J. P., and McLemore, B. F. 1967. Improving storage of spruce pine seed. U. S. Forest Serv. Tree Planters' Notes 18(2): 16.

Barnett, J. P., and McLemore, B. F. 1967. Germination of loblolly pine seed hastened by soakings in aerated cold water. U. S. Forest Serv. Tree Planters' Notes 18(2): 24-25.

Bonner, F. T. 1967. Germination of sweetgum seed in response to light. J. Forest. 65(5): 339.

Burns, Russell M. 1967. Gibberellic acid stimulates germination of sweetgum seed. Forest Sci. 13: 438-439.

McLemore, B. F., and Barnett, J. P. 1967. Effective stratification of spruce pine seed. U. S. Forest Serv. Tree Planters' Notes 18(2): 17-18.

Shoulders, E. 1967. Fertilizer application, inherent fruitfulness, and rainfall affect flowering of longleaf pine. Forest Sci. 13: 376-383, illus.

Artificial Regeneration--Nursery Practices, Seeding, and Planting

Brender, Ernst V., and Cooper, Robert W. 1968. Prescribed burning in Georgia's Piedmont loblolly pine stands. J. Forest. 66(1): 31-36.

Bonner, F. T. 1967. Ideal sowing depth for sweetgum seed. U. S. Forest Serv. Tree Planters' Notes 18(1): 17-18.

DeBell, Dean S., and Langdon, O. Gordon. 1967. A look at an 11-year-old hardwood plantation. Southern Lumberman 215(2680): 156-158.

Erdmann, Gayne G. 1967. Chemical weed control increases survival and growth in hardwood plantings. U. S. Forest Serv. Res. Note NC-34, 4 pp., illus.

Goebel, N. B., Brender, E. V., and Cooper, R. W. 1967. Prescribed burning of pine-hardwood stands in the upper Piedmont of South Carolina. South Carolina Agri. Exp. Sta., Dep. of Forest. Forest Res. Series No. 16.

Heidmann, L. J. 1967. Herbicides for preparing ponderosa pine planting sites in the Southwest. U. S. Forest Serv. Res. Note RM-83, 4 pp., illus.

Huntzinger, Harold J. 1967. Seeding black cherry in regeneration cuttings. U. S. Forest Serv. Res. Note NE-63, 8 pp.

Johnson, R. L. 1967. Improving germination of Nuttall oak acorns. U. S. Forest Serv. Res. Note SO-66, 3 pp.

Poljakoff, Mayber, A., and Gale, J. 1967. Effect of plant anti-transpirants on certain physiological processes of forest seedlings and other plant material. Final Report, PL-480 Project, A10-FS-10, Israel.

Ronco, Frank. 1967. Lessons from artificial regeneration studies in a cutover beetle-killed spruce stand in western Colorado. U. S. Forest Serv. Res. Note RM-90, 8 pp.

Shearer, Raymond C. 1967. Insolation limits initial establishment of western larch seedlings. U. S. Forest Serv. Res. Note INT-64, 8 pp., illus.

Shearer, Raymond C., and Halvorson, Curtis H. 1967. Establishment of western larch by spring spot seeding. J. Forest. 65(3): 188-193, illus.

Stoeckler, J. H. 1967. Seedbed density affects size of 3-0 green ash nursery stock. U. S. Forest Serv. Res. Note NC-25, 4 pp.

Webb, Charles D., and Darby, Sanford P. 1967. Ideal nurserybed density for sweetgum seedlings. U. S. Forest Serv. Tree Planters' Notes 18(2): 1-2.

Natural Regeneration

Bjorkbom, J. C. 1967. Seedbed-preparation methods for paper birch. U. S. Forest Serv. Res. Pap. NE-79, 15 pp., illus.

Croker, Thomas C., Jr. 1967. Crop-seedling method for planning brown-spot burns on longleaf pine. J. Forest. 65(7): 488.

DeBell, Dean S., and Auld, I. Dennis. 1967-68. Robins and tupelo in a low-country swamp. South Carolina Wildlife 15(1): 16.

Farmer, R. E., Jr., and Bonner, F. T. 1967. Germination and initial growth of eastern cottonwood as influenced by moisture stress, temperature, and storage. Bot. Gaz. 128: 211-215, illus.

Hall, Dale O. 1967. Slash disposal burns in pine patch-cuttings--a dialogue. U. S. Forest Serv. Res. Note PSW-148, 6 pp., illus.

Harris, A. S. 1967. Natural reforestation on a mile-square clearcut in southeast Alaska. U. S. Forest Serv. Res. Pap. PNW-52, 16 pp., illus.

Little, S. 1967. Treatments needed to regenerate yellow-poplar in New Jersey and Maryland. U. S. Forest Serv. Res. Note NE-58, 8 pp.

Marquis, David A. 1967. Clearcutting in northern hardwoods: results after 30 years. U. S. Forest Serv. Res. Pap. NE-85, 13 pp., illus.

Tubbs, Carl H. 1968. The influence of residual stand densities on regeneration in sugar maple stands. U. S. Forest Serv. Res. Note NC-47, 4 pp.

Wendel, George W., and Trimble, G. R., Jr. 1968. Early reproduction after seed-tree harvest cutting in Appalachian hardwoods. U. S. Forest Serv. Res. Pap. NE-99, 17 pp., illus.

Wiant, Harry V., Jr., and Powers, Robert F. 1967. Sprouting of old-growth redwood. Soc. Amer. Forest Proc., pp. 88-90.

Multiple-use Silviculture

Boyer, W. D. 1967. Grazing hampers development of long leaf pine seedlings in southwest Alabama. J. Forest. 65(5): 336-338, illus.

Broadfoot, W. M. 1967. Shallow-water impoundment increases soil moisture and growth of hardwoods. Soil Sci. Soc. Amer. Proc. 31: 562-564, illus.

Franklin, Jerry F., and Mitchell, Russel G. 1967. Successional status of subalpine fir in the Cascade Range. U. S. Forest Serv. Res. Pap. PNW-46, 16 pp., illus.

Solomon, Dale S., and Blum, Barton M. 1967. Stump sprouting of four northern hardwoods. U. S. Forest Serv. Res. Pap. NE-59, 13 pp., illus.

Stand Improvement

Alexander, Robert R. 1967. Windfall after clearcutting on Fool Creek, Fraser Experimental Forest, Colorado. U.S. Forest Serv. Res. Note RM-92, 11 pp.

Arend, J. L. 1967. Some variables affecting hardwood control with stem injections of 2,4,5-T. U. S. Forest Serv. Res. Pap. NC-18.

Boe, Kenneth N. 1967. Stocking control in the redwood region. Proc. 1966 Annu. Meet. of the Western Reforest. Coord. Comm., Portland, Oregon, pp. 42-44.

Clark, F. B. 1967. Pole-sized black walnut respond quickly to crown release. J. Forest. 65(6): 406-408.

Kormanik, Paul P., and Brown, Claud L. 1967. Adventitious buds on mature trees. U. S. Forest Serv. Res. Note SE-82, 7 pp.

Kormanik, Paul P., and Brown, Claud L. 1967. Root buds and the development of root suckers in sweetgum. Forest Sci. 13(4): 338-345.

Lowery, David P., and Schmidt, Wyman C. 1967. Effect of thinning of the specific gravity of western larch crop trees. U.S. Forest Serv. Res. Note INT-70, 6 pp., illus.

McGee, Charles E., and Smith, Robert C. 1967. Undisturbed rhododendron thickets are not spreading. J. Forest. 65(5): 334-335.

Minckler, Leon S. 1967. Release and pruning can improve growth and quality of white oak. J. Forest. 65(9): 654-655.

Animal Damage

Crouch, G. L. 1968. Clipping of woody plants by mountain beaver. J. Mammalogy 49(1): 151-152.

Harris, A. S. 1968. Small mammals and natural reforestation in southeast Alaska. U.S. Forest Serv. Res. Note PNW-75, 7 pp., illus.

Oh, Hikon, Sakai, T., Jones, M. B., and Longhurst, W. M. 1967. Effect of various essential oils isolated from sheep and deer on rumen microbial activity. Applied Microbiology 15: 777-784.

Radwan, M. A., and Campbell, D. L. 1968. Snowshoe hare preference for spotted catsear in western Washington. J. Wildlife Manage. 32(1): 104-108.

Radwan, M. A., Dodge, W. E., and Ward, H. S. 1967. Effect of storage on subsequent growth and repellency of Douglas-fir seedlings sprayed with TMTD. U.S. Forest Serv. Tree Planters' Notes 18(4): 10-13.

Growth Requirements

Allen, Robert M. 1967. Influence of the root system on height growth of three southern pines. Forest Sci. 13: 253-257, illus.

Fahn, A., and Waisel, Y. 1967. Factors controlling the annual rhythm of wood production. Final Report, PL-480 Project, A10-FS-5, Israel.

Helseth, Frank A., and Brown, C. L. 1967. The role of transpiration in the uptake of ^{45}Ca in slash pine. Proc. Ass. Southern Agr. Workers 64th Annu. Conv., p. 281.

Hook, Donal D., and Stubbs, Jack. 1967. Physiographic seed source variation in tupelo gums grown in various water regimes. Proc. Ninth Southern Conf. on Forest Tree Impr., pp. 61-64.

Krueger, K. W. 1967. Light intensity and amount of foliage influence root production of Douglas-fir seedlings. J. Forest. 65(3): 222 (Abstr.).

Krueger, K. W. 1967. Foliar mineral content of forest- and nursery-grown Douglas-fir seedlings. U.S. Forest Serv. Res. Pap. PNW-45, 12 pp.

Krueger, K. W., and Trappe, James M. 1967. Food reserves and seasonal growth of Douglas-fir seedlings. Forest Sci. 13: 192-202, illus.

Krueger, K. W. 1967. Nitrogen, phosphorus, and carbohydrate in expanding and year-old Douglas-fir shoots. Forest Sci. 13: 352-356, illus.

Krueger, K. W. 1967. Fall and winter photosynthesis and respiration of Douglas-fir seedlings. J. Forest. 65(3): 222 (Abstr.).

Kupila-Ahvenniemi, Sirkka. 1966. Physiological and morphological study on the vegetative and floral primordia of Scotch pine during the dormancy and the period of bud enlargement. Aquila, Ser. Bot. Tom. 4. Societas Amicorum Naturae Ouluensis, Univ. of Oulu, Oulu, Finland, PL-480 Project, E8-FS-48.

Kupila-Ahvenniemi, Sirkka, and Pihakashi, S. 1966. Qualitative study on the nucleic acids in the microsporangiate strobilus primordia and spur shoot primordia of the dormant Scotch pine. Annales Bot. Fennici 3: 117-122.

Kupila-Ahvenniemi, Sirkka, Karunen, M., and Pihakashi, S. 1966. Nucleic acid determination in the microsporangiate strobilus primordia and the spur shoot primordia of the dormant Scotch pine. Annales Bot. Fennici 3: 110-116.

Larson, M. M. 1967. Effect of temperatures on initial development of ponderosa pine seedlings from three sources. Forest Sci. 13: 286-294, illus.

Larson, Philip R. 1967. Effects of temperature on the growth and wood formation of ten Pinus resinosa sources. Silvae Genetica 16: 58-65.

Oppenheimer, H. R., and Kessler, B. 1968. Mechanisms of drought resistance in conifers of the Mediterranean Zone and the arid west of the U.S.A. Final Report, PL-480 Project, A10-FS-7, Israel.

Pachlewski, Roman. 1967. Investigations of pure culture of mycorrhizal fungi of pine. Final Report, PL-480 Project, E21-FS-17, Poland.

Paris, Richard P. 1967. Seasonal fluctuation in the foliage-moisture content of well-watered seedlings. Bot. Gaz. 128 (3-4): 179-185.

Schultz, R. P., and Woods, Frank W. 1967. The frequency and implications of intraspecific root-grafting in loblolly pine. Forest Sci. 13(3): 226-239.

RPA 101-APPRAISAL OF SOIL RESOURCES

Site Evaluation and Soil Improvement

Metz, Louis J., and Farrier, Maurice H. 1967. Acarina associated with decomposing forest litter in the North Carolina Piedmont. Proc. 2nd International Congress of Acarology, England.

Muma, Martin H., Metz, Louis J., and Farrier, Maurice H. 1967. New species and records of Phytoseiidae (Acarina: Mesastigmata) from North Carolina forest litter. The Florida Entomologist 50(3): 199-206, illus.

RPA 102-SOIL STRUCTURE-SOIL, WATER, PLANT RELATIONS

Artificial Regeneration

Jorgensen, J. R., and Shoulders, E. 1967. Mycorrhizal root development vital to survival of slash pine nursery stock. U.S. Forest Serv. Tree Planters' Notes 18, pp. 7-11.

TIMBER MEASUREMENTS AND MANAGEMENT PLANNING

(RPA 111 - TIMBER MANAGEMENT)

USDA and Cooperative Program

Location of Intramural Work	Scientist Man-years FY 1968
California	3.0
Colorado	1.0
Idaho	1.0
North Carolina	1.0
Ohio	1.0
Oregon	2.0
Total	9.0

Intramural program is supplemented by extramural support representing (a) 0 SMY's at State Agricultural Experiment Stations, (b) 1 SMY's at other U. S. institutions, 1/ and (c) 0 P. L. 480 funds in other countries.

1/ RPA 111.

Problems and Objectives

Intensive management of the commercial forests of the United States requires dependable, low cost methods of measurement of the contents of trees and stands, and more reliable prediction of future growth, yield, and quality of forest products. Productivity of forests, both in quality and quantity, varies markedly according to stand density, site quality, tree age, and species composition. Important forest regulation problems involving levels of growing stock, cutting budgets, and rotation lengths must be solved. With better information about the response of forests to various cultural practices, more attention must be given to planning and decision-making problems in order to guide management of large public and private timber holdings.

Major objectives of this research are to develop more efficient methods to:

1. Measure the contents of trees and stands.

2. Predict growth and yield of forest in response to various forest management practices.

3. Determine optimum solutions to such management planning problems as allowable cut, rotation ages, and levels of growing stock.

Progress - USDA and Cooperative Programs

A. Growth and Yield of Forest Trees and Stands

Standards for measuring and evaluating stocking and stand density have been developed for eastern hardwood forests from the growing space requirements of individual trees ranging from the open-grown condition to very dense conditions. These standards, widely tested throughout the hardwood region, are based on a simple tree count and an estimate of basal area per acre. Neither stand age nor site quality, both difficult to measure, are needed to appraise the stocking and density. These new standards provide both a diagnostic measurement of stand conditions and the implicit remedial action necessary for improved growth and yield.

Some 185,000 acres have been disturbed by open-pit mining in Kentucky, Virginia, Tennessee, Alabama, and Georgia; most of this acreage is in large private ownerships. Twenty-year-old experimental plantings on spoil banks near Jasper, Alabama, produced 20 cords per acre of loblolly

and 17 cords of shortleaf pine, in peeled wood, to a 3-inch top. Pine plantations on strip-mined land do not need any site preparation nor hardwood control. The coal industry's land reclamation problem offers a cost-saving solution to the paper industry's wood procurement problem.

Ponderosa pine, the most widely distributed pine in North America has considerable potential for timber production. Four experiment stations are completing installation of a comprehensive study of growing stock levels in even-aged stands throughout the West. The results of this west-wide study will help to determine optimum stand densities and rotation ages for a variety of management objectives.

The determination of productivity or site quality is fundamental to a great many forest management activities. Site index tables and curves have recently been completed for aspen and Engelmann spruce in the Central Rocky Mountains. Site curves have also been prepared for inland Douglas-fir, applicable within five subregions of the Intermountain west.

The dominant and codominant trees in many hardwood stands are often of sprout origin. It is not known whether these sprout trees are reliable indicators of site index. A recent study showed for red oak trees that were at least 35 years old, there were no significant differences in height-over-age relationships between sprout and seedling stems in the dominant and codominant crown classes. This information will greatly facilitate the determination of stand site index in areas where a high proportion of the stems are of sprout origin.

Stagnation, or a reduction of height growth, is common on average and poor sites for many timber species, but is generally considered unimportant on better sites. Two studies on good sites, one in slash pine in Georgia, the other in ponderosa pine in California both show that excessive early stocking will reduce height growth. In the ponderosa pine stand the reduction amounted to 26 feet after 31 years, compared to a more open stand. For slash pine the reduction was 10 feet after 17 years. Both of these studies emphasize that precommercial thinning may be necessary even on good sites in order to maintain height growth.

The manipulation of stand density and choice of site qualities are two of the primary tools by which foresters regulate tree growth. Growth of a 45-year-old Appalachian hardwood stand was studied on two sites (oak site index 85 and 63) under varying residual basal areas over a 10-year period. Stand growth in sawtimber trees was not affected by a reduction in residual density down to about 80 square feet on the excellent site and about 45

square feet on the fair site. However, there were large differences in growth between the two sites; the excellent site produced 1.4 times more cubic volume and 2.1 times more board foot volume than the fair site.

B. Forest Measurement

The costs of cruising and measuring trees and logs in the Pacific Northwest is about $15,000,000 annually. Timber measurement problems in the region were recently analyzed by consulting 120 representatives of different user groups. Log dimensions, quality, and defect were found to affect product yields in different and inconsistent ways. An optimum measurement system should provide direct estimates of all alternative end uses. This study should be the basis for discussion with the timber industry and timberland managers of the need and potential for improvements in timber measurement systems.

Closely related to these measurement problems in the Pacific Northwest is the preparation of highly flexible volume tables (or equations) for red alder to provide reliable estimates for a variety of forest products. These tables include upper stem diameters at 4-foot intervals, cubic volume above stump to six different diameter limits, and board-foot volumes to four different diameter limits by International 1/4-inch rule and by Scribner rule with three different scaling methods. These tables make possible consistent estimation of sawlog volumes of lower stems and cubic-foot volumes of upper stems of individual trees which are needed for multi-product utilization. The methods used here have application to many other timber species.

Three-P (probability proportional to prediction) is a new and efficient system of timber measurment that has stimulated much additional research. During the reporting year the following accomplishments related to the new system:

1. Estimates of gross volume on a timber sale in Oregon indicated that 3-P estimates of total sale volume and total sale value were notably free of sampling error, whether or not an optical dendrometer was used to measure the sample tree. If this experience is typical, estimates of total sale value under 3-P cruising may be sufficiently accurate to justify selling on the cruise.

2. Prompted a review of instruments for measuring upper stems of standing trees and evaluating their accuracy.

3. An elaboration on new units of tree measurement. A trio (volume, surface, length) and a pair (weight, length) of units of measure are far more efficient than any of the single scales now used (such as board feet, cords, or pounds) that are essentially nonlinear with respect to costs and product outturn.

4. An improved and greatly expanded version of an earlier computer program (1964) that converts dendrometer measurements of 3-P sample trees to population values in terms of whatever units the user desires.

A convenient handbook on statistical methods has been prepared for research workers who are rusty on procedures. The handbook tailored specifically for forestry problems describes standard statistical methods including chi-square tests, the t-test, analysis of variance, and regression analysis.

A second study on statistical method describes a powerful and expansible computerized system for regression or covariance analysis of as many as 50 variables, 8 of which may be dependent. Alternatively, it can screen variously generated combinations of independent variables to find the regression with the smallest mean-squared-residual, which will be fitted if desired.

Height-diameter curves commonly are used in conjunction with volume tables to estimate timber stand volume. A great many equation types have been used. A recent study identifies those easiest to fit by least squares and those that give unreasonable curve shapes. It also shows that when plots are remeasured a height-diameter-age equation will give more accurate and more consistent estimates of volume, periodic increment, and site index than individual curves.

C. Management Planning Procedures

By all odds, the most effective tool with which to implement management decisions relative to quantity, quality, and timing of wood yield is the control and manipulation of stand density and structure. A study completed for slash pine plantations in the South, utilizing recently developed diameter

distributional patterns, develops discounted present-value data, with and without differentials for tree size. The stand structure data are further utilized to demonstrate the effect of thinning on total yield and return. Results indicate that yields with and without thinning differ so little that costs, prices, and discount rates dominate biological considerations. This information gives the forest manager flexibility, the most valuable of management tools.

Hardwood pulpwood industries have generally been reluctant to invest in precommercial thinning until more is known about the growth of managed stands. Using the latest research data and applying reasonable costs it has been shown that pulpwood yields can be greatly improved by making precommercial thinnings. For example, on a 50-year pulpwood rotation estimated yields ranged from 32 cords per acre in unmanaged stands to 54 cords per acre in managed stands. The investigation points out three problems that the pulpwood industry faces, namely: the need to develop cheaper methods of thinning, the need for better planning of the distribution of age-classes, and the need to modify timber cutting operations to preserve and enhance the beauty of the landscape.

Many southern landowners are not aware of the high returns that are possible from the sale of poles, nor do they understand how to manage land for optimum pole production. In site-90 stands stocked with 55 to 130 square feet of basal area per acre, pulpwood-sawtimber production yielded two-thirds the stumpage returns realized by producing poles, pulpwood, and sawtimber. The integration of pole production with pulpwood and sawtimber production has increased stumpage returns, at age 35, an average of $174 per acre, or about $5 per acre per year. As stand density decreased, poles developed faster but returns per acre decreased. Industrial foresters and small landowners, when made aware of the high returns possible from the sale of poles and understand better how to manage their stands, may consider integrating pole production into their woods operation.

As the demand for southern hardwood pulping species increases, and as more land is withdrawn for agriculture, interest grows in the improvement of hardwood cultural practices on suitable sites. Research indicates that short rotations of cultivated plantations on good sites will yield a per-acre annual average of 3.3 cords for cottonwood, 1.5 cords for sycamore, and 0.9 cords for sweetgum. Longer rotations, producing logs as well as pulpwood, provide greater flexibility to meet changing market demands, and at present stumpage prices will yield a higher return. Even with emphasis on longer rotations there will be plenty of pulpwood from thinnings.

Publications - USDA and Cooperative Program

Growth and Yield of Forest Trees and Stands

Alexander, Robert R. 1967. Site indexes for Engelmann spruce in the central Rocky Mountains. U. S. Forest Serv. Res. Pap. RM-32, 7 pp.

Brickell, James E. 1968. A method for constructing site index curves from measurements of tree age and height--its application to inland Douglas-fir. U. S. Forest Serv. Res. Pap. INT-47, 23 pp., illus.

Collins, A. B. 1967. Density and height growth in natural slash pine. U. S. Forest Serv. Res. Pap. SE-27, 8 pp.

Gingrich, S. F. 1967. Measuring and evaluating stocking and stand density in upland hardwood forests in the Central States. Forest Sci. 13(1): 38-53.

Jones, John R. 1967. Aspen site index in the Rocky Mountains. J. Forest. 65(11): 820-821, illus.

Myers, Clifford A. 1967. Growing stock levels in even-aged ponderosa pine. U. S. Forest Serv. Res. Pap. RM-33, 8 pp.

Oliver, William W. 1967. Ponderosa pine can stagnate on a good site. J. Forest. 65(11): 814-816, illus.

Plass, W. T., and Burton, J. D. 1967. Pulpwood production potential on stripmined land in the South. J. Soil and Water Conserv. 22: 235-238, illus.

Trimble, G. R., Jr. 1968. Growth of Appalachian hardwoods as affected by site and residual stand density. U. S. Forest Serv. Res. Pap. NE-98, 12 pp.

Trimble, G. R., Jr. 1968. Multiple stems and single stems of red oak give same site index. J. Forest. 66(6): 198.

Forest Measurement

Bruce, David. 1968. Forest mensuration--tree-measuring instruments. McGraw-Hill Yearbook of Sci. and Technol., pp. 191-192, illus.

Bruce, David. 1967. A dendrometer field calculator. J. Forest. 65(8): 566-567, illus.

Bruce, David. 1967. New tools and methods in forest mensuration. In Measuring the Southern Forest, Thomas D. Keister, ed., Louisiana State Univ. 15th Annu. Forest. Symp. Proc. 1966: 83-92. Also, U. S. Forest Serv. Res. Note PNW-67, 10 pp.

Bruce, David, and Cowlin, Robert W. 1968. Timber measurement problems in the Douglas-fir region of Washington and Oregon. U. S. Forest Serv. Res. Pap. PNW-55, 29 pp., illus.

Curtis, Robert O. 1967. Height-diameter and height-diameter-age equations for second-growth Douglas-fir. Forest Sci. 13: 365-375, illus.

Curtis, Robert O., Bruce, David, and VanCoevering, Caryanne. 1968. Volume and taper tables for red alder. U. S. Forest Serv. Res. Pap. PNW-56, 35 pp.

Freese, Fran. 1967. Elementary statistical methods for foresters. U. S. Dep. of Agr. Handbook 317, 87 pp., illus.

Grosenbaugh, L. R. 1967. Choosing units of measure. In Proc. of Conf. on young-growth forest management in California. Univ. California Agr. Ext. Serv. pp. 143-147.

Grosenbaugh, L. R. 1967. REX--Fortran-4 system for combinatorial screening or conventional analysis of multivariate regressions. U. S. Forest Serv. Res. Pap. PSW-44, 47 pp., illus.

Grosenbaugh, L. R. 1967. STX--Fortran-4 program for estimates of tree populations from 3-P sample-tree-measurements. U. S. Forest Serv. Res. Pap. PSW-13, 76 pp., illus., 2nd. ed., rev.

Johnson, Floyd A., Dahms, Walter G., and Hightree, Paul E. 1967. A field test of 3-P cruising. J. Forest. 65(10): 722-726.

Management Planning Procedures

Bassett, John R. 1967. Pole production in natural loblolly pine stands near Crossett, Arkansas. U. S. Forest Serv. Res. Note SO-58, 5 pp., illus.

Bethune, James E. 1967. Manipulation of stand density in planted southern pines for maximum pulp yields. Proc. 4th Forest Biology Conf. of the Tech. Ass. of the Pulp and Pap. Ind., Pulp and Paper Research Institute of Canada, pp. 111-119. (Also accepted for publication in TAPPI).

McKnight, J. S. 1967. A new look at hardwood for pulping. Pulp and Pap. 41(14): 83-84.

Roach, B. A., and Gingrich, S. F. 1967. Upland hardwoods can be grown efficiently. Amer. Pulpwood Ass., Pulpwood Annu., pp. 85-87.

FOREST GENETICS

USDA and Cooperative Program

Location of Intramural Work	Scientist Man-Years F.Y. 1968		
	Research Problem Area		Total
	111	301	
California		5.2	5.2
District of Columbia	1.0		1.0
Georgia		3.0	3.0
Idaho		1.9	1.9
Illinois		2.0	2.0
Mississippi		9.2	9.2
New Hampshire		5.0	5.0
Oregon		4.0	4.0
Wisconsin		7.0	7.0
Total	1.0	37.3	38.3

Intramural program is supplemented by extramural support representing (a) 0.0 SMY's at State Agricultural Experiment Stations, (b) 0.0 SMY's at other U.S. institutions, and (c) P.L. 480 funds in 11 countries representing 215,000 U.S. dollars equivalent.

Problems and Objectives

Genetic improvement of forest trees is one of the most promising approaches to increasing the efficiency of timber production, improving timber quality, and reducing pesticide hazards. Trees bred for rapid growth, good form, desirable wood quality, and pest resistance are urgently needed in reforestation programs. Improved trees must be provided for planting under intensive culture in order for the Nation to meet its timber needs in the future.

Major objectives of the research are:

1. To determine the degree of inherent variation of important traits.

2. To develop effective hybridization and breeding schemes for improving these traits.

3. To devise the most efficient methods for producing superior trees.

Progress - USDA and Cooperative Program

RPA 111 - TIMBER MANAGEMENT

Identification, Classification, and Distribution of Forest Trees

Southern forests are composed of many species of plants in a complex ecology. An understanding of the interrelationships among species is necessary for effective management of these forests. About 100 different species of trees, shrubs, and vines were collected from the Bluff Experimental Forest near Vicksburg, Mississippi, during the period 1961 through 1965. An annotated list describes trees by size, tolerance, growth, and abundance classes, shrubs by size and abundance, and vines by abundance. The list will serve as a reference of the woody plants in and around the forest and will provide information on some silvical characteristics of species classified as trees.

Pines on Santa Cruz and Santa Rosa Islands off the coast of Southern California are a source of genetic material which has been neglected in the past. Recently the island populations were mapped and cone, needle, and resin collections made. Many of the island trees resembled mainland bishop pine, Pinus muricata D. Don. However, some of the variants (trees with smooth cones) had previously been named P. remorata Mason.

After further examinations of collected material and comparisons with mainland bishop pine, it was concluded that P. remorata type trees were essentially trees expressing the variation normally existing within bishop pine. Seed will be grown and arboreta established for further work with these trees. With a clear understanding of the relationship of these pines with other California pines, hybridization studies can be properly directed.

RPA 301 - IMPROVEMENT OF BIOLOGICAL EFFICIENCY OF TREES

A. Inherent Variation

The use of superior clones of cottonwood in plantations would result in increased quantity and quality of timber production over unselected material currently in use. Results from a test of 49 random cottonwood selections demonstrated that expected gains from selecting the best 10 percent of the clones would be: first year height 9 percent; diameter 11 percent; number of branches 19 percent; and resistance to melampsora rust 73 percent. More extensive collections of clones are being tested. Those with superior attributes will be identified and, through asexual reproduction which retains the full genetic potential of the material, used to establish commercial plantations.

The extent of racial variation in yellow-poplar, one of the South's most widely planted hardwoods, is of considerable importance to the intensive silvicultural and breeding research now underway. In a recent test, yellow-poplar from four sources in the coastal plain and the Cumberland Plateau was planted in four replicated plantings near the seed origins. Juvenile growth has been good, suggesting that yellow-poplar from these sources can be successfully planted over the sampled area. Seedlings from seed collected near Gloster, Mississippi, have survived on the Cumberland Plateau and those from seed collected near Sewanee, Tennessee, have grown well in central Mississippi. Apparently yellow-poplar's adaptive response to climatic variation over the test region is not great enough to seriously penalize movement either north or south. Most of the observed variation in growth is related to site and follows an easily predicted pattern. Variation in dates of bud-break and growth cessation followed expected patterns, with trees from northern sources beginning growth later and ending it earlier than those from southern provenances.

Interlocked grain occurs most frequently in hardwood species and is undesirable because it often causes severe warping in lumber and plywood. Within sweetgum, interlocked grain is the result of repeated changes in

both direction and angle of spiral among growth rings caused by changes within a single ring with increasing height above the ground. Within each of 19 stands sampled in the Southeast, there was important variation among individual trees in the severity of the defect. Some trees were found that were almost straight grained. The range of variation and the pattern of variation suggest that selection and breeding can produce a strain of sweetgum with straight grain.

Sweetgum is the only species of its genus indigenous to the United States. Other species of this genus may be useful for planting or may have superior traits that could be introduced into the native species through hybridization. Forty-two sources of an exotic species from Taiwan (Liquidambar formosana) were planted in south Mississippi where climate is similar to that of L. formosana's natural range, first year height and diameter did not differ significantly between the two species. After two years in the nursery formosan gum seedlings had higher mean specific gravity and longer fibers than seedlings of sweetgum. If these wood property relationships remain consistent as the trees mature, considerably more wood substance will be produced per unit of volume by the L. formosana. The oriental species could then be used in breeding to increase both specific gravity and fiber length of the native sweetgum, making a significant contribution to the South's hardwood culture.

The range of variation is now being studied for the first time in yellow birch with 55 collections from throughout the species' range. In the nursery, sources from West Virginia and lower Michigan grew almost twice as much as the poorest source, and most sources performed better than the local Wisconsin source. Height growth was independent of geographic source and appears to vary in a random manner. Growth cessation was inversely correlated with latitude and showed some relationship with average July temperature, and annual precipitation. These preliminary results indicate that although seed sources can be found which may be better than local sources, a major program of individual tree testing will be essential in yellow birch breeding.

In selecting superior pine trees, workers often give appreciable weight to cone-producing ability. A study in Florida showed that cone-producing ability in slash pine is inherited to a moderately strong degree, with broad-sense heritability being about .50. Narrow-sense heritability, however, seems to be relatively weak. The results indicate that in order to increase seed production in clonal orchards, fruitfulness can be included as a criterion in selection. However, because of the indicated low narrow-sense heritability, such selection would probably not be very effective when seedling seed orchards are used.

The worth of a seed orchard can be increased by measuring the relative values of the parent trees and removing the lower value parents. A study in Georgia compares the relative values of 35 selected trees based on the performance of their progeny. It indicates that for some growth characteristics gains of 10 to 24 percent may be obtained from the best parents. The data also identify those parents whose production of substandard progeny make them candidates for removal from the orchard.

The importance of utilizing seed from suitable geographic sources has long been recognized in pine planting programs in the United States. To obtain a better understanding of these sources differences, observations were made on the terminal growth phenology of 6-year-old slash pine from 14 geographic sources in a northeastern Florida plantation. Differences in time of beginning of terminal growth were minor. But provenances from the north-central portion (optimal climate zone) of the species range had greatest total growth and grew more rapidly during the early portion of the season than did other sources. Sources from peninsular Florida grew more than other provenances in late summer.

Provenance plantings established from 1937 to 1957 have shown also some differences in slash pine. More recent and very intensive studies of morphological and juvenile characters have verified that the species varies genetically from place to place within its range. There is considerable evidence that growth-rate differences attributable to geographic location are not of practical significance within the center of the natural range. Similarly, on favorable sites there was little difference in survival or fusiform rust resistance. North or west of the species range, however, or on droughty sites anywhere, trees of northern or western provenance generally survived best. Slash pine seeds collected from indigenous stands in the north Florida-south Georgia area appear suitable for planting or seeding within or near the natural range of the species. General restrictions for moving slash pine seed within its natural range can be relaxed according to these findings.

Recent results of several long-term studies of loblolly pine indicate that substantial losses could be incurred by the use of seed from the wrong geographic source, particularly if seed is moved from north to south. Conversely, worthwhile gains may be obtained from the use of seed moved short distances south to north. Results after 10 years of an intensive study of seed source differences in Georgia show that seed may be moved inland or northward and exceed the local source in growth,

though perhaps being more susceptible to fusiform rust and surviving less well initially. Coastal Plain sources exceeded Piedmont sources in growth in the Piedmont but not in the mountains. There, Piedmont sources were best.

However, in a similar study on the Cumberland Plateau in Tennessee, eight-year-old loblolly pine saplings from middle and lower Piedmont Georgia seed sources had 11 percent mortality in the severe winter of 1962-63. Sixty-eight percent of the trees suffered varying degrees of damage. In an adjacent plantation, six-year-old loblolly trees from a local Tennessee source were completely uninjured. Increment cores and stem internodes show a definite loss of growth. Loblolly pine will be less susceptible to winter damage if the seed is from a source close to the planting site. Carelessness in choosing the seed source can mean substantial financial losses to landowners planting loblolly pine if seed are moved to the south or too far north.

Red pine (Pinus resinosa Ait.) is one of the most important conifers for planting in the north-central and northeastern States. Results of a provenance study in Pennsylvania show that there were only minor differences among 50 seed sources (mostly from the Lake States) in survival and height growth up to 5 years of age, but there were significant differences for average total heights at 10, 20, and 25 years. Trees from seed sources from southerly latitudes had better height growth than those from the northerly latitudes. On the Allegheny Plateau where there is no local red pine seed source, certain Lake States seed-collection zones will be good sources. This study also has provided data on the extent of variability in red pine which will be valuable in planning tree improvement programs.

To guide in the selection and testing for wood characteristics, and in the breeding of jack pine for better wood quality 34 sources were selected for a study of tracheid length and specific gravity at 5 years of age. There were significant seed source differences in these two characteristics in three-year-old wood. Seed sources from Northern Canada and Eastern Nova Scotia had the slowest growth rate, shortest tracheids, and highest specific gravity. Sources from Minnesota, Wisconsin, and Michigan had the highest growth rate, longest tracheids and lowest specific gravity. Tracheid length as estimated from three-year-old wood may give a fair indication of mature-tree tracheid length; thus, early selection of the best seed sources may be possible. Specific gravity of three-year-old material is unlikely to be useful in predicting the wood density of mature trees, but the relative value will aid in selection.

In a study important to California Christmas tree growers, results suggest that greater care must be taken in selecting the proper seed source for future white fir planting in the mid-elevations of the Sierra Nevada. When seedlings from seed collected at 43 different locations throughout the range of white fir were grown at the Institute of Forest Genetics, Placerville, those seedlings from the northernmost seed collections sustained severe winter injury at 3 years of age. The injury was characterized by browning of needles and needle drop. This information is important to an understanding of seed-source variation as well as being of practical significance to Christmas tree growers.

In many parts of the world, particularly the Southern Hemisphere, exotic tree species have exceeded native species in growth. Many exotic species have been tried in the U.S. and some have performed well as ornamentals or in special situations. None has been successful for large-scale plantation culture. One of the older arboreta was established at Wind River, Washington in 1912. The half-century worldwide search for better forest trees for Oregon and Washington indicates that none are candidates to replace native species. Many outgrew native trees in their early life but all developed weaknesses later.

A PL-480 project in Poland is investigating geographic variation in Scots pine, one of the few successful exotic forest trees widely planted in the U.S. for such special purposes as Christmas trees. These scientists have reported significant variation associated with geographic origin in numerous traits such as growth, needle morphology, photosynthesis and respiration. Their work seeds to define the interactions of source with growing conditions and provide information on the best sources for specific planting locations and uses.

B. Hybridization

Hybrid poplars have high potential as pulpwood trees because of fast growth. However, the true potential must be evaluated in terms of both growth rate and specific gravity, since both factors determine the amount of pulp that can be produced in a given time. In a West Virginia planting, 13 of 50 hybrid clones showed promising growth rates. Among these 13 clones, there was a difference of 0.09 in specific gravity; the heaviest was 24 percent higher than the lightest. This information will enable selection of a hybrid poplar clone with maximum pulpwood potential.

Exploratory crossing of pine species, much of it done at Placerville, California, has shown that the two principal groups of pines--the soft (or white) pines and the hard (or yellow) pines--behave very differently in species crosses. The yellow pines can generally be crossed only with similar species native to the same part of the world. Ponderosa pine, widespread in the Western United States, is a good example. It crosses with many other western and Mexican species, but it cannot be crossed with any pine of Europe, Asia, or even the Southeastern United States. White pines of the Eastern and Western Hemispheres, on the other hand, can often be successfully crossed. Western white pine, for example, can be crossed with white pines native to the Eastern United States, Japan, the Himalayas of Asia, and the Balkans of Europe. Knowledge of the crossability relationships now make it possible to plan long-range hybridization programs efficiently and to avoid costly attempts at breeding among incompatible species.

Natural hybrids have been reported among many important forest species. In some cases they are very vigorous and quite desirable, in other cases they do not equal the better parent and should be discriminated against. Pitch pine is a common species in southern New Jersey and was formerly considered to grow in much of the Coastal Plain of Delaware and Maryland. Pond pine was known to occur in portions of the Maryland and Delaware Coastal Plain and more rarely in southern New Jersey. Loblolly pine is common in the lower Coastal Plain of Maryland and Delaware and is naturalized in portions of southern New Jersey. A reported study serves to (1) more accurately define the range of these tree species, especially of pitch pine (2) show that natural hybrids and intergrades occur among the three species, and (3) show that intergrades between loblolly and pond pines are common in southern Delaware and eastern Maryland. Distinguishing characteristics are described. Recognition of the differences is important, because at 50 years loblolly pine is 13 to 15 feet taller and larger in diameter than pond pine on typical Eastern Shore sites. Many of the intergrades or hybrids are intermediate in growth and form. Consequently, typical loblolly pines should be selected in seed collections for forest nurseries or as seed trees in harvest cuttings.

C. Methods Used in Tree Breeding

The commonly accepted method of selecting trees for tree improvement programs is to comb the woods for outstanding mature trees. This can be expensive both in time and labor. One of the principal reasons for selecting only in mature stands has been lack of knowledge concerning the relationship between juvenile performance and mature tree development. In a study in Georgia outstanding nursery seedlings of loblolly and slash

pines were selected at 1 year of age and studied for 9 years in test plantations. The results show that a substantial number of selected trees were capable of sustained high performance, and at 9 years the selected trees averaged 20 to 22 percent more cubic-foot volume than randomly selected comparison trees.

This study supports the hypothesis of high correlation between juvenile traits and subsequent development. The technique will be useful for screening large numbers of seedlings for rapidly growing trees.

The degree of genetic gain from seed orchards will depend to a large extent on the effectiveness of isolation zones used to minimize pollen contamination from nearby wild stands. In the South a 400-foot isolation zone is commonly used, but its effectiveness has not been proven. In Florida a study was designed to measure effectiveness. When male flowers were removed from trees within an experimental orchard, normal yields of viable seed were still obtained. This study points out the need for a new research on the problem of pollen contamination.

In a survey study in Oregon, pollen contamination of six Douglas-fir seed orchards from local stands ranged between 2,900 and 7,000 grains per square inch in 1966, a heavy seed year. Other years were lighter but still gave serious contamination. This sampling shows pollen contamination to be a more serious problem than anyone expected.

Forest trees pose special problems in genetic data analyses because of the environmental variation encountered and the long periods of time. New analytical procedures are being developed to cope with these problems and multiple-trait evaluation. The analysis and interpretation of provenance tests for several traits simultaneously is often desirable but rarely done. Research in North Carolina shows that a multiple regression analysis of multivariate data is a feasible method of reducing the data to essential parameters. The application of the techniques to many provenance selection problems will simplify them and provide sound analyses and interpretations for the guidance of tree breeders.

Successful controlled pollinations are dependent, in part, on knowing the receptive period of female flowers. This period determines not only when pollinations must be made to obtain seed, but also how long the flowers must be protected to avoid contamination with foreign pollen. Recent research in Mississippi has found that sweetgum flowers are receptive over approximately a four-week period. Pollination which will result in good seed yields can be made over a 3-week period commencing when staminate flowers appear to be fully expanded. Protective bags should

remain on the flowers 3 weeks after anthesis to avoid contamination. The development of controlled pollination techniques and the relatively long period of receptivity of female flowers makes sweetgum one of the easier southern trees to breed.

Interest in the genetic improvement of sycamore is increasing rapidly. In another Mississippi study, results indicate that much of the reputed low germination in this species may be due to self-incompatibility. Trees that are growing singly or that occur as scattered individuals in a mixed stand may not receive adequate pollen from other trees. Germination tests conducted at the Eastern Tree Seed Laboratory at Macon, Georgia, corroborated by x-ray analysis, revealed 30-80 percent normal germination from cross-pollinated seed. Only 0-2 percent of the seed resulting from self-pollination germinated normally. No viable seed were obtained from isolated, unpollinated flowers in this species where seed developed even though unpollinated. This information is being used by tree breeders in new programs and provides guidance on seed orchard lay-out to insure adequate cross-pollination. Selfing will not be a problem as it is in some other species.

DNA is the basic genetic material in living organisms, therefore, studies of even gross differences within and between species may give us important clues to species' behavior. In Wisconsin the DNA content and the nuclear volumes in root meristems were determined for 13 evergreen coniferous species. The differences in DNA amounts from the lowest to the highest of the species studied varied by a factor of about 3.2. Conifers possess, overall, more DNA per cell than broadleaf trees. The small sample of species studied indicates that a relationship may exist between nuclear volume of meristematic root cells and extent of species distribution. The results support the hypothesis that species with small amounts of DNA per cell possess a greater degree of adaptation to the environments.

Incompatibility between scion and stock is a serious problem in the establishment of clonal seed orchards of Douglas-fir. Because the incompatibility often does not become evident until the grafts are several years of age, the loss is great in time and expense. Research in Oregon has found that incompatible clones always display a wounding and rehealing symptom detectable at the beginning of 2nd-year growth. With this knowledge and technique it is now possible to identify the troublesome clones early and avoid the time and expense of grafting incompatible clones for seed orchard planting and consequent future losses. A related study has shown graft survival and growth are directly related to length of cambial contact.

Under a PL-480 grant, a team of scientists in Italy studied the problem of graft incompatibility. Grafts between different pine species varied in success, apparently depending on genetic factors of individual trees within species. Anatomical studies showed that the period of intense cambial activity is most favorable to graft success. Incompatibility also may be due to differences in age of scion and stock, expressed in physiological and biochemical processes. Biochemical studies showed that success is higher when scion and stock have similar enzyme patterns, which occurs most often in young material of closely related individuals. These studies have provided sound basic information that increases the probability of solving the problem of graft incompatibility.

Basic research on rooting is being conducted under several PL-480 grants. In India recent results show that initiation and development of roots on stem cuttings of Bryophyllum is dependent on photoperiod and that treatment with auxins can be substituted for the short day requirement. Study of 35 tree species confirms that the effectiveness of auxin treatments varies with season; the effect of a particular auxin may be reversed between seasons.

Though a great deal is known about the environmental conditions that favor rooting, virtually nothing is known about the internal physiology and biochemistry of rooting. A PL-480 project in Spain resulted in new knowledge about plant compounds associated with ease of rooting. Extracts obtained from five easy-to-root species (currant, two willows, sycamore, and fig) and four difficult-to-root species (Chestnut, oak, walnut, and ash) were studied. The results suggested that p-hydroxybenzoic acid may be responsible for stimulating root initiation in easy-to-root cuttings and that gentistic, salicylic, and some other unidentified acids may be the inhibitors in difficult-to-root cuttings, but these findings are not conclusive. The root promoters were also found in the difficult-to-root species but apparently chemically bound in unavailable form. The compounds were tested for growth activity on oat seedlings but were not actually tested for root-promoting action. These findings are, however, the most promising leads developed so far in the search for the causes of rooting differences.

Monterey pine is one of the easier yellow pines to root, but rooting success decreases with age of parent. Another problem with pines is the limited number of branch tips available for cuttings so activity has centered on rooting the short shoots in needle fascicles. In Chile, under PL-480, experiments were performed to find out how to root short shoots

of Pinus radiata D. Don and to cause them to sprout. Best rooting conditions for short shoots were: a basic treatment with IBA 50 ppm for 24 hours, then planting at 20-25°C. under 12 hours of light per day. Fascicles from trees older than 9 years could not be rooted. There were strong suggestions that root-forming capacity was unequally distributed along the stem and that rooting capacity showed seasonal fluctuations. Best time for taking cuttings under central Chilean conditions seemed to be winter and early spring. A zone of maximum short shoot bud length was found and 58 percent of rooted fascicles from this zone sprouted. Further study of mortality of rooted fascicles where buds had begun elongations showed that the failure was due to the absence of connecting vascular tissue between roots and shoot. This new information is a major step toward mass vegetative reproduction of pines.

Publications - USDA and Cooperative Program

RPA 111 - TIMBER MANAGEMENT

Identification, Classification, and Distribution of Forest Trees

Franklin, Jerry F., and Greathouse, Thomas E. 1968. Cotyledon numbers in the noble-California red fir species complex. Northwest Sci. 42: 32-33. (Abstr.)

Johnson, R. L., and Little, E. L., Jr. 1967. Trees, shrubs, and woody vines of the Bluff Experimental Forest, Warren County, Mississippi. U.S. Forest Serv. Res. Pap. SO-26, 14 pp., illus.

Linhart, Y. B., Burr, B., and Conkle, M. T. 1967. The closed-cone pines of the northern Channel Islands. Symp. Biol. Calif. Islands Proc., pp. 151-177, illus.

RPA 301 - IMPROVEMENT OF BIOLOGICAL EFFICIENCY OF TREES

Inherent Variation

Barnes, Burton, V. 1967. Phenotypic variation associated with elevation in western white pine. Forest Sci. 13(4): 357-364, illus.

Bengtson, G. W., McGregor, W. H. D., and Squillace, A. E. 1967. Phenology of terminal growth in slash pine: some differences related to geographic seed source. Forest Sci. 13(4): 402-412.

Boyer, W. D. and Evans, S. R. 1967. Early flowering in longleaf pine related to seed source. J. Forest. 65(11): 806.

Clausen, Knud, E. 1968. Variation in height growth and growth cessation of 55 yellow birch sources. Eighth Proc. Lake States Tree Impr. Conf. (In press)

Conkle, M. T., Libby W. J. and Hamrick, J. L., III. 1967. Winter injury among white fir seedlings...unusual pattern in seed source study. U. S. Forest Serv. Res. Note PSW-138, 7 pp.

Farmer, R. E., Jr., Russell, T. E., and Krinard, R. M. 1967. Sixth-year results from a yellow poplar provenance test. Ninth Southern Conf. on Forest Tree Impr. Proc., pp. 65-68.

Henry, Berch W., and Wells, Osborn, O. 1967. Variation in brown-spot infection in longleaf pine from several geographic sources. U. S. Forest Serv. Res. Note SO-52, 4 pp., illus.

Hough, Ashbel F. 1967. Twenty-five year results of a red pine provenance study. Forest Sci. 13: 156-166, illus.

Jewell, F. F., and Mallet, S. L. 1967. Testing slash pine for rust resistance. Forest Sci. 13: 413-418, illus.

King, James P. 1968. Seed source variation in tracheid length and specific gravity of five-year-old jack pine seedlings. Eighth Proc. of Lake States Forest Tree Impr. Conf. (In press)

Kraus, John F. 1967. A study of racial variation in loblolly pine in Georgia--tenth-year results. Ninth Southern Conf. on Forest Tree Impr. Proc., Knoxville, Tenn., pp. 78-85.

La Farge, Timothy, and Kraus, John F. 1967. Fifth-year results of a slash pine polycross progeny test in Georgia. Ninth Southern Conf. on Forest Tree Impr. Proc., Knoxville, Tenn., pp. 86-91.

Mignery, A. L. 1967. Winter injury to loblolly pine in Tennessee related to seed origin. Southern Lumberman 215(2680): 146, illus.

Silen, Roy R. 1967. Wind River Arboretum--a pioneer search for better kinds of trees for the Northwest. (A self-guided tour pamphlet.) U. S. Forest Serv., PNW Forest and Range Expt. Sta., 10 pp., illus.

Snyder, E. Bayne, Wakeley, Philip C., and Wells, Osborn O. 1967. Slash pine provenance tests. J. Forest. 65(6): 414, 420, illus.

Sorensen, Frank. 1967. Two-year results of a west-east transect-provenance test of Douglas-fir in Oregon. U. S. Forest Serv. Res. Note PNW-72, 8 pp.

Varnell, Ray J., Squillace, A. E. and Bengtson, G. W. 1967. Variation and heritability of fruitfulness in slash pine. Silvae Genetica 16(4): 125-128.

Webb, Charles D. 1967. Interlocked grain in Liquidambar styraciflua L. Proc. 14th IUFRO Congress, Munich, Germany. 10: 398-412.

Wilcox, J. R. 1967. Seedlings of two Liquidambar species compared. Ninth Conf. on Forest Tree Impr. Proc., pp. 59-60.

Wilcox, J. R. and Farmer, R. E., Jr. 1967. Variation and inheritance of juvenile characters of eastern cottonwood. Silvae Genetica 16(5-6): 162-165.

Zelawski, W. and Goral, I. 1966. Seasonal changes in the photosynthesis rate of Scots pine (Pinus silvestris L.) seedlings grown from seed of various provenances. Acta Societatis Botanicorum Poloniae, Vol. XXXV, Nr 4, pp. 587-598.

Zelawski, W., and Gowin, T. 1966. Variability of some needle characteristics in Scots pine (Pinus silvestris L.) ecotypes grown on the comparative plantation. Ekologia Polska--Seria A, Tom XIV, Nr 17, pp. 275-283.

Zelawski, W., and Niwinski, Zygmunt. 1966. Variability of some needle characteristics in Scots pine (Pinus silvestris L.) ecotypes grown in native conditions. Ekologia Polska--Seria A, Tom XIV, Nr 19, pp. 301-308.

Zelawski, W. and Kinelska, Jr. 1967. Photosynthesis and respiration of Scots pine (Pinus silvestris L.) seedlings grown in water culture from seed of various provenance. Acta Societatis Botanicorum Poloniae, Vol. XXXVI, Nr 3, pp. 495-503.

Zelawski, W. and Kinelska, J. 1967. Photosynthesis and respiration of Scots pine (Pinus silvestris L.) seedlings of various provenance grown under different light conditions. Acta Societatis Botanicorum Poloniae. Vol. XXXVI, Nr 4, pp. 713-723.

Zelawski, W. and Zelawska, Barbara. 1967. Some aspects of the effect of shade on growth of Scots pine (Pinus silvestris L.) seedlings of various provenances. Ekologia Polska--Seria A. Tom XV, Nr 5, pp. 107-114.

Hybridization

Critchfield, William B. 1967. Crossability and relationships of the closed-cone pines. Silvae Genetica 16: 89-97, illus.

Critchfield, W.B., and Krugman, S.L. 1967. Crossing the western pines at Placerville, California. Univ. Wash. Arboretum Bull. 30: 78-81, illus.

Hamilton, J.R. and Wendel, G.W. 1968. Specific gravity and fiber length of some hybrid poplars growing in West Virginia. West Virginia Univ. Agr. Exp. Sta. Bull. 556T, 6 pp.

Little, Elbert L., Jr., Little, Silas, and Doolittle, Warren T. 1967. Natural hybrids among pond, loblolly, and pitch pines. U.S. Forest Serv. Res. Pap. NE-67, 22 pp.

Methods Used in Tree Breeding

Baccar, V., et.al. 1967. The problem of grafting incompatibility in the grafting of forest trees. Final Report, PL-480 Project, E15-FS-6, Italy.

Beland, J.W., and Jones, LeRoy. 1967. Self-incompatibility in sycamore. Ninth Southern Conf. on Forest Tree Impr. Proc., pp. 56-58, illus.

Bey, Calvin F. 1967. Obtaining genetically identical black walnut seedlings. Ill. Quality Nut Tree 6(1): 5-8, illus.

Callaham, R.Z. 1967. Hybridizing pines with diluted pollen. Silvae Genetica 16(1): 121-215. Also in Proc. Eighth Southern Conf. on Forest Tree Impr., pp. 110-111, 1965.

Clausen, Knud E., and Godman, Richard M. 1967. Selecting superior yellow birch trees, a preliminary guide. U.S. Forest Serv. Res. Pap. NE-20, 10 pp., illus.

Copes, D.L. 1967. Influence of cambial contact length on graft survival and leader elongation in Douglas-fir. U.S. Forest Serv. Res. Note PNW-69, 8 pp., illus.

Copes D.L. 1967. A simple method for detecting incompatibility in 2-year-old grafts of Douglas-fir. U.S. Forest Serv. Res. Note PNW-70, 8 pp., illus.

Firenzuoli, A.M., et. al. 1967. Effect of tween 80 on protein- tannic acid complex. Separatum Experientia 23, 3 pp.

Firenzuoli, A.M. et. al. 1967. Use of tween 80 in ferredoxin extraction from gymnosperms. Phytochemistry 6: 1633-1635.

Gansel, Charles R. 1967. Are genetic gains from seed-production areas small? J. Forest. 65(9): 634-635.

Hoffman, V.A., and Kummerow, J. 1966. Anatomische beobachtungen zur bewurzelung der kurztriebe von Pinus radiata. Silvae Genetica 15: 35-38.

Hunt, Davie L. 1967. Ninty-year performance of slash and loblolly pine nursery selections in Georgia. Ninth Southern Conf. on Forest Tree Impr. Proc., Knoxville, Tenn., pp. 92-94.

Hyun S.F. 1967. Physiological differences among trees with respect to rooting. Proc. 14th IUFRO Congress, Munich, Germany, 10: 168-190.

Ikan, R. and Ozeri, Y. 1966. Detection of the terpenoids of Pinus halepensis by spot tests. Israel J. Chemistry 4: 251-252.

Jewell, F.F., and Walker, N.M. 1967. Histology of Cronartium quercuum galls on shortleaf pine. Phytopathology 57: 545-550.

Krugman, S.L. 1967. A gibberellin-like substance in immature pine seed. Forest Sci. 13(1): 29-37.

Krugman, S.L., and Critchfield, W.B. 1968. Red pine needle structure. Nature 217: 685-868.

Kummerow, Jochen. 1966. Vegetative propagation of Pinus radiata by means of needle fascicles. Forest Sci. 12(4): 391-398.

Miksche, J.P. 1967. Radiobotanical parameters of Pinus banksiana. Naturwissenschaften 54: 322.

Miksche, J.P. 1967. Variation in DNA content of several gymnosperms. Canadian Jour. Genetics and Cytology 9: 717-722.

Namkoong, G. 1967. Multivariate methods for multiple regression provenance analysis. Proc. 14th IUFRO Congress, Munich, Germany, 3: 308-318, illus.

Nanda, K.K., Purohit, A.N., and Bala, Adarsh. 1967. Effect of photoperiod, auxins and gibberellic acid on rooting of stem cuttings of Bryophyllum tubiflorum. Physiologia Plantarum 20: 1096-1102.

Nanda, K.K. et. al. 1968. Seasonal rooting response of stem cuttings of some forest tree species to auxins. Indian Forester 94(2): 154-162.

Rudolph T. D. The effects of X-irradiation of seed on X_1 and X_2 generations in Pinus banksiana Lambert. Radiation Bot. 7: 303-312.

Silen, R. 1967. Earlier forecasting of Douglas-fir cone crops using male buds. J. Forest. 65(12): 888-891, illus.

Silen, R. 1968. Sampling of pollen contamination within Northwest seed orchards. Indus. Forest. Ass. Newsletter No. 7.

Sorensen, Frank. 1967. Linkage between marker genes and embryonic lethal factors may cause disturbed segregation ratios. Silvae Genetica 16: 132-134.

Squillace, A.E. 1967. Effectiveness of 400-foot isolation around a slash pine seed orchard. J. Forest. 65(11): 823-824.

Vazquez, A., Vieitez, E., et. al. 1967. Substances isolated from woody cuttings of Salix atrocinerea and their growth properties. Physiologia Plantarum 20: 232-244.

Vazquez, A., Vieitez, E., et. al. Growth substances isolated from woody cuttings of Castanea sativa mill. Phytochemistry 6: 913-920.

Vazquez, A., Vieitez, E., et. al. 1967. Compounds isolated from woody cuttings of Platanus orientalis L. and their growth promoting activity. Anales de Edafologia y Agrobiologia Tomo XXXVI, Nums 1-4, pp. 131-144.

Vazquez, A., Vieitez, E., et. al. 1966. p-Hydroxybenzoic acid, a growth regulator, isolated from woody cuttings of Ribes rubrum. Physiologia Plantarum 19: 294-307.

Wilcox, J.R. 1967. Duration of pistillate flower receptivity in sweetgum. Forest Sci. 13: 95-96, illus.

Zanobini, A., et. al. 1967. Effect of tween 80 on protein-tannic acid complex. Separatum Experientia 23: 1-3.

Zanobini, A., et. al. 1967. Use of tween 80 in ferredoxin extraction from gymnosperms. Phytochemistry 6: 1633-1635.

TIMBER-RELATED CROPS

USDA and Cooperative Program

Location of Intramural Work	Scientist Man-Years F.Y. 1968		
	Research Problem Area		Total
	111	905	
Florida	5.0		5.0
Kentucky		2.0	2.0
Nebraska		2.0	2.0
North Dakota		5.0	5.0
Pennsylvania		1.0	1.0
Vermont	5.0		5.0
Total	10.0	10.0	20.0

Intramural program is supplemented by extramural support representing (a) 0.0 SMY's at State Agricultural Experiment Stations, (b) 0.0 SMY's at other U.S. institutions, and (c) P.L. 480 funds in 3 countries representing 50,078 U.S. dollars equivalent.

Problems and Objectives

The forests of the United States produce a number of timber-related forest crops, some of which are sources of important industries. These products include naval stores, maple sap, Christmas trees, and a group of minor crops composed of edible, medicinal, and decorative materials. Some of these crops, independently or in combination with timber production, greatly enhance the total income of forest owners. These crops also provide a ready cash income to individuals in many low-income areas. Another important aspect of timber-related crops is the establishment and maintenance of shelterbelts on the Great Plains and the development of special-purpose tree plantings and other forestry practices to improve the quality and appearance of rural and urban environments. The demands are great for knowledge on how to grow and maintain trees in areas being engulfed by today's urban sprawl. Trees are an important aspect of recreation and beauty in our modern environment.

Major objectives of the research are:

1. To determine the potential of timber-related crops to contribute to rural economies.

2. To develop efficient methods of producing maple sap, gum naval stores, Christmas trees, and medicinal and decorative plants.

3. To develop improved trees for planting on the Great Plains to reduce erosion, protect crops, ameliorate the environment and provide natural beauty.

4. To develop methods to establish and maintain shelterbelts and other plantings of trees to improve the environment.

5. To develop cultural techniques to establish and grow trees in urban and suburban environments, with emphasis on establishment methods, plant materials, and maintenance of tree vigor.

Progress - USDA and Cooperative Program

RPA 111 - TIMBER MANAGEMENT

A. Naval Stores

For over 20 years spraying a 50 percent water solution of sulfuric acid on freshly prepared wounds has been an accepted method for turpentining the

southern pines. This treatment when applied at 14-day intervals, gives satisfactory gum yields, but the liquid acid is hazardous to workers and corrosive to the metal cups and gutters used for gum collection. A new acid paste formulation developed at Olustee, Florida, corrects the more objectional features of using sulfuric acid as a gum flow stimulant. In addition, this paste will prolong gum flow for 21 to 28 days. Pilot plant tests have resulted in labor savings of 30 to 50 percent over the presently used acid-water solution method. A patent has been granted. Since the major need of the gum naval stores industry is to reduce production costs, this invention will be of tremendous benefit to gum producers.

The common method for gas chromatographic analysis of pine monoterpenes is to distill oleoresin and inject only the essential oil portion into the gas chromatograph. However, unequal loss of the monoterpenes prior to analysis resulted in highly variable results. A newly developed technique utilizes the injection of solid samples of pine needle, wood, and bark tissue into the gas chromatograph. With this technique very small samples of plant material can be analyzed without depending on oleoresin exudation or extraction. The procedure provides reproducible results even when samples are as small as 10 mg. of pine needle tissue or a portion of a simple vertical resin duck from a 5 mm. increment core. The development of this analytical method not only increases production per man-day, but also greatly increases the accuracy of the analyses.

Fundamental studies of water stress in the bole of slash pine have been conducted in an effort to determine its relationship to oleoresin exudation. It has been found that exudation pressure is related to moisture stress. Pressures are highest just before dawn and decrease throughout the day. Understanding these relationships within the tree is necessary before sound recommendations can be developed for cultural measures that influence moisture supply.

B. Maple Sap Production

Plastic tubing for sap collection has been acclaimed as a major factor in modernizing the 300-year-old maple sap industry. Tubing reduces labor costs, keeps sap cleaner, and reduces loss to spillage, yet it is used by only a small proportion of the producers. Two basic systems are in use, vented and unvented, but the better system had not been determined. Research at Burlington, Vermont, has shown that an unvented system with suspended lines has a substantial production advantage--43% in the 1966 season. Further, it was determined that the increase was related to the development of a natural vacuum in the system, thus opening the way for

further gains by vacuum pumping. The gains to be achieved through higher yields and better sap quality from unvented systems will give this multi-million dollar industry a substantial boost and it will be reflected in the rural economy.

Tapping causes stained and unproductive wood above and below the taphole, and keeping track of old holes year after year becomes a problem for the maple sap producer. To help the producer quickly identify old tapholes a simple taphole marker consisting of a short strand of weather resistant material anchored in a wooden dowel has been developed. The dowel is placed in the old taphole with the marker protruding. When the marker is no longer visible a new taphole can be drilled in the same place without encountering unproductive wood. Use of the taphole marker should increase efficiency in tapping operations particularly in sugarbushes that will be in continuous production for many years.

Information on the biology of flowering and fruiting in sugar maple is needed to facilitate breeding improved trees. A recent four-year study shows that certain trees have a greater capacity than others for seed production when self-pollinated and when out-crossed to the same male parent. Incompatibility, found in other plants to prevent seed set after self-pollination, was not observed. Variation in seeds set after self-pollination were primarily due to the post-fertilization abortion of ovules. Trees that show a higher degree of self-sterility also show a greater tendency toward cross-sterility. Fruit sets from unpollinated flowers ranged from 36.0 to 94.4 percent among the trees used in the study, but only 3 filled fruits were found among 272 unpollinated flowers indicating that apomixis is of small consequence. This information is basic to a successful breeding program with sugar maple.

RPA 905 - TREES TO ENHANCE RURAL AND URBAN ENVIRONMENT

A. Shelterbelts

Some meadow sites in sandhills areas of Nebraska and other Plains States are either too wet or too alkaline for best growth of conifers. Yet, livestock protection windbreaks are needed in these areas. Some hybrid poplars widely cultivated throughout the world for rapid shelter protection as well as for wood production appear reasonably well adapted for these wet-meadow sites. Of 21 different poplar hybrids tested for 10 years at several locations in Nebraska, hybrids of Populus deltiodes x P. nigra cv. Caudina were the best. They grew 30 to 40 feet tall in 10 years, were straighter and more narrow-crowned than common native cottonwood, and

have appeared relatively free of disease cankers to date. These promising results indicate that some of these clones are immediately useful in the Plains and suggest the creation of new hybrids between selected parents from these two species.

Production of conifer tree stock of sufficient size and quality for field planting in the Plains normally takes 2 to 4 years. Nursery space and cost of planting stock could be reduced if seedlings grew to required sizes in less time. Use of lights at night to extend the daily photoperiod has stimulated growth. Larger seedlings of ponderosa and Austrian pines, eastern red cedar, several oak species, and cottonwood were grown under 24 hours continuous light (using supplemental white lights at night) than under normal 14 hours daylight. Supplemental lights used only 1 or 2 hours during middle of night gave an intermediate growth response. Supplemental lighting should be terminated by September 1 to allow proper hardening off to prevent frost damage. It appears that one year may be cut from the time required to grow ponderosa pine planting stock. In another experiment it was found the gibberellic acid can be used to stimulate growth of oaks in the nursery. This establishes another approach to the solution of the problem of high quality planting stock in a shorter period of time.

B. Other Timber-Related Crops

There is a pressing need for genetically better street and park trees: trees that are acceptable from the standpoint of growth-rate and growth-habit; trees adaptable to a wide range of environmental conditions; and trees resistant to disease, insects, and air pollutants. A paper, presented at the annual meeting of the New Jersey Federation of Shade Tree Commissions, was based on more than forty years of tree improvement research, and observations on many tree species suitable for amenity planting. It provides the guidelines for selecting and immediately utilizing superior individuals, and for producing better amenity trees through selective breeding and hybridization. These guidelines are needed by shade tree associations and individuals in the field and can be put into immediate use.

Field experiments often require the use of expensive and sensitive recording equipment. There is a need for a sturdy portable shelter that can be used in the forest. Researchers at Burlington, Vermont, have solved this problem by designing and building a 4 x 8 foot instrument shelter that will withstand the rigors of the climate and yet can be assembled or dismantled in less than 20 minutes by two men. The heaviest piece weighs only 100 pounds and can be easily carried into the woods by two men. Plans are available.

Publications - USDA and Cooperative Program

RPA 111 - TIMBER MANAGEMENT

Naval Stores

Brown, C. L., and Helseth, Frank A. 1967. Indirect measurements of water stress in the bole of slash pine. Proc. Ass. Southern Agr. Workers, Inc. 64th Annual Convention, p. 275.

Clements, Ralph W. 1967. Composition and methods for stimulating flow of pine gum. U.S. Patent No. 3, 359, 681.

Clements, Ralph W. 1967. Acid paste method highly successful in commercial operations. AT-FA J. 30(1): 4, 6-7. Naval Stores Review 77(6): 4, 6, 9.

Harrington, T.A. 1967. Errors in use of acid paste and suggested remedies. AT-FA J. 29(7):10-11. Also, with the title Errors in acid paste use, suggested remedies. Naval Stores Review 77(1): 8.

Lane, John M. 1967. First-year results: 366 barrels of gum from 8 monthly paste streaks. Naval Stores Review 77(2): 4, 8. Also in AT-FA J. 29(9): 12-14.

Roberts, Donald R. 1968. Use of solid sample technique for pine oleoresin gas chromatographic analysis. J. Gas Chromatography 6: 126-127.

Simpson, E.B. 1965. Intermediarios fosforilados en la biosintesis de terpenos en un sistema soluble de plantulas de Pinus radiata Don. Anales de la Facultad de Quimica y Farmacia, pp. 119-123.

Sirota, A.Y. 1965. Estudios quimicos y enzimaticos en tejidos de Pinus radiata. Anales de la Facultad de Quimica y Farmacia, pp. 36-40.

Maple Sap Production

Blum, Barton M. 1967. Plastic tubing for collecting maple sap: a comparison of suspended, vented and unvented installations. U.S. Forest Serv. Res. Pap. NE-90, 13 pp., illus.

Blum, Barton M. 1967. A taphole marking device. National Maple Syrup Digest 6(3): 8-9.

Gabriel, William J. 1967. Reproductive behavior in sugar maple: self-compatibility, cross-compatibility, agamospermy, and agamocarpy. Silvae Genetica 16: 165-168.

Koelling, M. and Blum, B. 1967. Controlling taphole depth in maple sap production research. U.S. Forest Serv. Res. Note NE-61, 4 pp., illus. (Results previously reported in National Maple Syrup Digest 1967. 6(2): 16-17.

RPA 905 - TREES TO ENHANCE RURAL AND URBAN ENVIRONMENT

Shelterbelts

Read, Ralph A. 1967. Hybrid poplar performance at 10 years in the Nebraska sandhills. U.S. Forest Serv. Res. Note RM-91, 8 pp.

Read, Ralph A., and Bagley, W.T. 1967. Effect of gibberellic acid spray on seedlings of eastern red cedar, bur oak, and red oak. U.S. Forest Serv. Res. Note RM-82, 2 pp.

Read, Ralph A., and Bagley, W.T. 1967. Response of tree seedlings to extended photoperiods. U.S. Forest Serv. Res. Pap. RM-30, 16 pp.

Van Haverbeke, David F. and Boldt, C.E. 1968. Vigor and density of shelterbelt conifers can be improved. J. Forest. 66(3): 187-192.

Other Timber-Related Crops

Davidson, Walter H., and Dawson, David H. 1968. Trees and shrubs for roadside beautification in the northern Plains. The Dakota Farmer.

Koelling, Melvin R. 1967. A portable field shelter. U.S. Forest Serv. Res. Note NE-70, 4 pp., illus.

Plass, William T., and Boyce, Stephen G. 1967. Aesthetic forests for urban areas. Parks and Recreation 2(10): 42, 73,90. (Reprints not avail.)

Schreiner, Ernst J. 1966. Guidelines for selecting and producing genetically better trees for street and park planting. New Jersey Federation Shade Tree Commission Proc.: 38-43.

WATERSHED, RECREATION, AND RANGE RESEARCH

FOREST SOIL AND WATER RESEARCH

USDA and Cooperative Programs

Location of Intramural Work	Scientist Man-Years F.Y. 1968			
	Research Problem Area			Total
	107	105	901	
Alaska	3.2			3.2
Arizona	8.0			8.0
Arkansas	1.0			1.0
California	9.0	1.0		10.0
Colorado	10.2			10.2
Idaho	3.7			3.7
Kentucky	7.0			7.0
Michigan	2.0			2.0
Minnesota		2.0		2.0
Mississippi	3.0	1.2		4.2
New Hampshire	2.8			2.8
New Mexico	4.0			4.0
New York	1.0			1.0
North Carolina	4.0			4.0
Ohio	2.0			2.0
Oregon	3.0		2.8	5.8
Pennsylvania	2.3			2.3
South Carolina		2.0		2.0
South Dakota	2.0			2.0
Utah	6.0			6.0
Washington	5.2			5.2
West Virginia	1.2			1.2
Wisconsin	2.0			2.0
Wyoming	2.1			2.1
Total	84.7	6.2	2.8	93.7

Intramural program is supplemented by extramural support representing (a) 0 SMY's at State Agricultural Experiment Stations, (b) 0 SMY's at other U.S. institutions, and (c) P.L. 480 funds in two countries representing $39,500 U.S. dollars equivalent.

Problems and Objectives

Present water demand for agricultural, industrial, and municipal uses is estimated to be about 270 billion gallons of fresh water per day. Although much of this water is returned to streamflow, shortages already exist. Considering fresh water only, future demands call for almost 400 b.g.d. by 1980 and almost 600 b.g.d. by the year 2000. The most logical place to look for additional supplies of high-quality water is in river headwaters which are in forests, associated rangelands, or alpine regions. Forest Service research has produced scientific evidence that streamflow can be sustantially increased by a variety of vegetative management techniques. At the same time, these watershed lands must be managed carefully to repair damage from past mismanagement and to prevent any future damage to rural lands.

The aims of forest soil and water research are to devise methods for:

1. Improving water yields for agriculture, industry, and municipal use.

2. Preventing watershed damage by timber harvesting, logging road construction, and grazing.

3. Restoring natural beauty and soil stability in watersheds damaged by farming, grazing, mining, and fire.

4. Improving productivity of wetland and upland forest soils.

5. Preventing pollution of soil and water.

Progress--USDA and Cooperative Programs

RPA 107 - TECHNOLOGY OF WATERSHED CONSERVATION AND MANAGEMENT

A. Improvement of Water Supplies for Agriculture, Industries, and Municipalities by Watershed Management.

More water from snowpacks. Increased runoff from Fool Creek watershed (710 acres) in the Colorado Rocky Mountains, shows no signs of diminishing 11 years after an experimental cutting of timber. The additional flow comes from increased deposits of snow in alternating strips that have been cleared of timber. The resulting water bonus each year averages enough to cover Fool Creek watershed with 4 inches of water--about 237 acre-feet--over 77 million gallons.

Snowmelt in Colorado was accelerated an average of 2.8 times by spreading carbon black on snow at the rate of 319 pounds per acre. Scientists have found that speed of melting is highly correlated with net radiation (incoming solar radiation minus outgoing radiation) over the snow surface. Carbon black reduces outgoing radiation thus increasing net radiation and speed of melt. Some evidence was also found that carbon black suppresses evaporation from snow surfaces.

Time-lapse motion pictures used in alpine areas of Colorado have revealed airflow patterns of drifting snow. Snow fences, erected in alpine areas to increase the depth of downwind drifts, have occasionally been ineffective; the movie technique reveals some aerodynamic quirks that cause snow to pack against the upwind side of the fence. This prevents deep buildup of a leeward drift which is wanted to supply late-summer-streamflow from alpine areas.

Rime ice formation amounted to as much as 1,600 gallons per acre per day, water equivalent, in upper slope forests of eastern Washington. Riming occurs when supercooled moisture droplets comprising winter fog collide with obstructions in the windstream--in this case the branches of lodgepole pine. The Washington study was recorded by time-lapse photography of daily weather factors with periodic sampling of amounts of water equivalent. The total contribution by rime ice to seasonal or annual water input is not known, but it represents a measurable credit to the moisture balance.

These findings represent an advance in our knowledge of snow, the most important source of water in the West. The goal is to learn how to manage snowpacks on a broad scale to maximize usable streamflow for agriculture, industrial growth, and community development.

More water by manipulation of vegetation. A spectacular increase in streamflow has been obtained by cutting and deadening all vegetation on a 39-acre watershed in New Hampshire. In the first year after cutting and herbicide spraying, the annual water yield increased 1.125 acre-feet or 367,000

gallons from each acre. Most of this gain--63 percent--occurred during the late summer and fall when normal streamflow from undisturbed forest lands is at the lowest point of the year.

Water yield has increased about 110,000 gallons per acre per year from Workman Creek in the Salt River Valley of Arizona where moist-site forest cover (dominantly white fir and Douglas-fir) was converted to perennial grass on 80 acres. Increases in yield were obtained every month of the year, but 80 percent of the annual amount occurred during the 8 cooler months, October through May. Increased water yields are tremendously important in the Salt River Valley, which surrounds Phoenix; the Salt River Valley Users' Association is cooperating in this study.

The foliage of a 60-year-old white pine plantation at the Coweeta Hydrologic Laboratory in the Great Smoky Mountains of North Carolina intercepts twice as much precipitation as a mature hardwood stand. Intercepted moisture is held by the needles, twigs, branches, and trunk of the pine tree and never reaches the ground or adds to streamflow. In the same study, it was found that a 10-year-old plantation intercepts 2 inches (20 percent) more precipitation than the mature hardwood stand. This helps explain the finding in 1966 that streamflow from this young plantation was 3 inches less than would have come from the original hardwood stand it replaced.

Increased water yields from a chaparral-covered watershed in central Arizona have resulted from chemical treatments to kill brush and perennial forbs. One study near Roosevelt Reservoir has shown water yield increases as high as 275,000 gallons to as low as 27,000 gallons per acre per year--depending on the annual precipitation. Records of these increases are still not sufficient to provide a reliable figure of average increase possible for the chaparral type. Moreover, the great range of annual yields must always be considered in planning water developments.

Best gains in streamflow are obtained in areas where deep-rooted vegetation can be removed. Aspen roots extend to depths exceeding 9 feet in high-elevation watershed lands in Utah, enabling the tree to deplete soil moisture to those depths. Management of aspen must include consideration of its high water consumption. Studies have shown that as much as 5 inches of moisture (about 135,000 gallons per acre) can be conserved in the upper 6 feet of soil by aspen removal for increased water yield. Aspect as well as elevation affects moisture removal: more soil moisture is used on west slopes than on north- or south-facing slopes.

Water yields can be predicted. As more and more data show that streamflow can be increased by management of vegetation, it becomes possible to predict potentialities for increasing water yields in a specific area. Such a prediction was prepared by watershed scientists of the Forest Service for municipal watershed managers in Massachusetts: a complete clearcutting of a watershed area will probably increase the water yield of that area about

8 inches annually. This increase is equivalent to 220,000 gallons from each acre treated.

Another forecast technique is to relate rates of snowmelt to expected seasonal flows. Aerial photography is being used to observe snow-cover depletion at the Fraser Experimental Forest in the central Rocky Mountains. Snow scientists find that the rate of depletion of the snowpack is highly correlated with seasonal amounts of runoff from this snowmelt. Year after year, the patterns of snow depletion and generated runoff have been similar, even though the amount of snow and weather conditions that produced runoff were not the same. The relationships developed here offer promise for making short-term streamflow forecasts for power production, irrigation, and municipal use.

Water for communities. Experimental subwatersheds within the Bull Run Watershed, source of water for Portland, Oregon, annually yield over 100 inches of water. This is an extremely large amount--more than 2.7 million gallons from each acre of drainage area. Even in dry years about 70 inches of water are yielded. These streams in their undisturbed state carry almost no suspended seiment and have a dissolved solid content of only about 25 parts per million. Water balance studies are in progress.

Recreation on municipally owned watersheds in the Northeast has not seriously degraded public water supplies, but this may have been due to the determined efforts of watershed managers to minimize recreation on reservoirs and watershed lands. Some types of outdoor recreation are compatible with water supply management but they must be supervised carefully. Continued greater pressure for recreation may be met by assigning a recreation specialist to the staff of the water supply administrator. Much more research is needed on the effect of recreation on water quality.

B. Protection and Wise Stewardship of Forest Soil and Water Resources.

In Hawaii, it has been found that soil can be protected from erosion by conversion of vegetation. Although parent rock material was found to be the most important factor related to erodibility, the erosive characteristics of soil is associated also with different kinds of vegetative cover. Soils on which native koa-ohia scrubby forests were growing were high in easily eroded small aggregates. In contrast, soils under the kukui and planted forests of paperbark and silk oak have greater water-stability qualities. Planting of the latter group of trees should be promoted for the dual need to protect soil and produce an income from the land.

Another form of soil loss results from mass movement of soil bodies. Precise measurements of natural soil creep to depths of 60 feet have been made in the northern Coast Range of California. On the basis of these measurements, annual sediment contributions in some regions have been determined to be in excess of 750 tons per square mile. Only occasionally have soil creep and other processes of mass soil movement been recognized as playing a

significant role in modifying the landscape. But this study clearly establishes soil creep as a major erosion process. Future research will attempt to show the effect of vegetation and timber management on this process.

Soil disturbance from Wyssen skyline logging was not much less than that from high-lead logging on a 237-acre clear-cut unit in the western Cascades of Oregon. In this type of terrain the chief benefit from skyline logging is the need for far less road construction--about one third as much as is necessary for high-lead logging. Roads cause considerable increase in sediment movement and often they are the source of mass soil movements.

Environment for fish and wildlife. Maximum stream temperatures increased as logging progressed on a northwest-facing watershed on the west side of the Cascade Range in Oregon. Temperature increases became statistically significant when 65 percent of the 237 acres were logged. When the drainage area was entirely logged, the increase averaged 4° F. during July and August. On an adjacent watershed, increases up to 16° F. were recorded where the stream flowed 1,300 feet through a scoured portion of the channel with no shade. But a decrease of 8° F. was measured after this heated water flowed 700 feet further through an undisturbed area with normal shade. Cool water is required as an environment for fish and other aquatic life, and is highly desirable for municipal and industrial uses.

C. Reduction of Human and Economic Loss From Floods.

Studies in the lower coastal plain of South Carolina show that large volumes of streamflow leave wetland watersheds soon after rainstorms, particularly when the water table is at or above ground level; total stormflow is twice as great in coastal plain wetlands as in the mountains and the Piedmont. Engineers who use a common drainage formula without correction for soil moisture storage capacity of wetland forests can underestimate peak flows during wet periods by 60 percent, resulting in underdesign of bridges, culverts, ditches, and other control measures.

Underdesign for wetland conditions can also affect the productivity of these sites. A survey of 41 metal culverts on logging and other work roads in northern Minnesota showed that culverts too small in diameter or poorly placed caused damming of the natural water drainage, resulting in the flooding and killing of much timber and an appreciable amount of road erosion. Placement problems were poor culvert slope, poor hydraulic approach, lack of gravel bedding, and too little soil covering the culverts.

On the average, flood flows have not been increased by complete removal of vegetation from one-half of a small watershed in West Virginia. Although annual yield from this area increased 7.4 inches, storm peaks over a 3-year period were higher than expected only on two occasions--when heavy precipitation followed a dry spell--and these flows were well below flood stage. They were the result of higher soil moisture in the cleared area reducing storage capacity for a portion of the storm rainfall.

Many floods can be traced to fires. In southern California, wildfires often condition the soil so that it resists wetting. But a recent study has shown that the application of a wetting agent--such as a detergent--to water resistant soils in southern California has allowed rains to penetrate the soil and stimulate growth of grass. Following brush fires, seeding of common rye grass and other grass species is a remedial measure for erosion control on the unstable soils. The study showed that the greatest stimulation of grass growth was on the steeply sloping soils that had been treated to make them less water resistant. Thus, moisture conditions became more favorable for plant establishment and growth.

Wetting agents used in treating water-resistant soils are relatively expensive, costing between $18 and $31 per acre for materials and application. Thus, discretion in their use is necessary. Another study in southern California determined that one treatment would remain effective after leaching by 16 inches of precipitation--the average annual amount of rainfall in the affected area. Therefore, treatment would not have to be repeated more than once per year under normal weather conditions.

New ideas for flood warning. Contrary to widespread belief, a snowpack does not always act as a sponge, absorbing water and providing flood protection. In a recent study in the Sierra Nevada, 10 inches of water at 35° F. were applied to a 5-foot snowpack over a 30-hour period. At the end of the experiment, none of the applied water was left in the pack; it moved through the snow and into the soil. These measurements were made possible by the gamma-transmission profiling snow gage developed by this project.

Another historic snow hydrology theory appears to be in error according to information obtained from the profiling snow gage. Instead of finding that the snowpack begins to melt when it reaches a uniform density of 45 percent, snow scientists in the Sierra Nevada found that the 1966 pack never attained a uniform density. When it began to melt on April 1, densities ranged from 27 to over 50 percent. As the melt water moved downward, low-density layers were eroded by moving water and were actually decreased in density.

Both of these discoveries increase our knowledge of snowpack mechanics. Better understanding of snow hydrology will increase the accuracy of flood warning systems and prediction of reservoir storage.

D. Restoration of Soil Stability, Natural Beauty, and Income Opportunity.

Longfingergrass, a bunchgrass from South Africa, appears to have good potential for erosion control and forage in the South. It has survived and grown rapidly on bare, sandy soil in north Mississippi. Each plant produced many above-ground runners or stolons, some as long as 12 feet. Along the runners, a new plant with roots developed wherever a node came in contact with soil. It will grow on unfavorable soil such as bulldozer fill, without fertilizer and with relatively low rainfall.

Another plant useful for protection of soil is squaw carpet, Ceanothus prostratus, which may be propagated successfully from cuttings and also by seed. A laboratory study in Nevada has developed the know-how for both methods. Squaw carpet is a Sierra Nevada ground cover plant that thrives on very harsh sites and is used for rehabilitating damaged watersheds. It has been successfully planted far from its native range.

Alkali sacaton, one of the most desirable plants for revegetating damaged watersheds in New Mexico, requires more moisture for initial establishment than several other range plants. In a laboratory study at Albuquerque, seeds of alkali sacaton were more severely affected by moisture stress than seeds of galleta and blue grama. This helps to explain why alkali sacaton plants are confined mainly to areas that are frequently flooded. The other two species, less affected by moisture stress, can become established on the drier upland sites.

Waterline stabilization was found to be essential in rehabilitating eroding streambanks in Michigan. Rock riprapping is the usual procedure for waterline control. After undercutting was stopped, the upper banks were revegetated in 1 to 5 years. Without waterline control, all revegetation efforts were ineffective. Revegetation is speeded by seeding with grasses and by fertilization, but in 4 years natural revegetation on untreated banks was nearly equal to that on the seeded banks. Research on this problem not only leads to stabilization of stream channels but also contributes to restoration of streamside beauty and improved fish habitat.

Selective mixtures of herbaceous plants show promise of indicating areas that will support tree growth within generally toxic spoils from strip-mined areas in the central Appalachians. The toxicity of some spoils cannot readily be identified, even with chemical testing. But these herbaceous plants can provide a rapid, inexpensive method of determining whether or not trees can be successfully established. The procedure may be adapted to aerial application, and can be used on large areas needing rehabilitation.

Rehabilitation of strip-mined lands should be planned before mining. Plantings on experimental plots in Alabama, Tennessee, and Kentucky show that much strip-mined land offers good potential sites for growing southern pines. Although growth rates are not as fast as on good pine sites, they should equal the growth on abandoned farmland. Most of the 185,000 acres of strip-mined land in the southern Appalachians has some type of vegetation on it, but forest management for pulpwood production on the suitable portions of this area would provide for greater returns than on unmanaged lands. Within the procurement area of a pulpmill, the opportunity exists for coal and paper companies to cooperatively plan reforestation programs, for a profit, before mining is started. Thus, reforestation for rehabilitating disturbed land can also serve to improve income opportunities in impoverished rural areas.

An open-cast mine in Great Britain is similar to a strip mine in the United States. But in Great Britain, where land is at a premium, restoration of disturbed land has been given uncommon urgency, and pre-mining planning is an integral step in each mining operation. Although the disturbed areas are usually easier to reclaim in Great Britain than here because of smaller operating areas and more favorable soils and climate, their costs range from $3,000 to $9,000 per acre. This is about 10 times the expenditure in the United States. Although we still have sufficient land to allow a longer and less expensive period of restoration, opportunities for each country to learn from the other are evident.

RPA 105 - CONSERVATION AND EFFICIENT USE OF WATER FOR AGRICULTURE

Red alder, the major hardwood tree of the Pacific Northwest, contributes to soil fertility in much the same way as do leguminous plants to agricultural lands. Soil nitrogen is substantially increased and association with red alder significantly improves growth of coniferous trees. Furthermore, antibiotic substances produced by soil microflora beneath red alder trees may inhibit tree disease organisms. Therefore, an opportunity exists to achieve high soil fertility and disease inhibition without use of chemicals.

Three nutrients, calcium, magnesium, and sodium, are being lost by undisturbed watersheds in the White Mountains of New Hampshire. Studies of nutrient cycling in these forest ecosystems compare incoming nutrients--in precipitation and air--with outgoing nutrients in streamflow. Potassium was the only nutrient studied that did not show a net loss. Presumably the losses were derived from chemical decomposition of bedrock and overlying till. These basic studies provide a baseline from which to measure changes caused by watershed treatments.

After clearcutting one of the White Mountain experimental watersheds, the net loss increased drastically. Concentrations of calcium, magnesium, sodium, and potassium in stream water increased from 3 to 20 times over that from adjacent undisturbed watersheds. The results indicate that this ecosystem has limited capacity to retain excess nutrients. When vegetation is no longer present to take up the nutrients, they pass out of the system with the larger quantity of water being yielded.

Increased resource value of wetlands. Mathematical models for predicting soil moisture levels and oxygen diffusion rates have been developed and tested at drained wetland sites near Charleston, South Carolina. Prediction of these two factors will supplement other well known models used to predict water table fluctutations in drained land. Soil moisture levels and oxygen diffusion rates above the water table may be among the primary factors governing plant root extension in wetlands; which, in turn, is related to tree vigor. Thus, another step is taken toward the goal of improving productive capacity of coastal wetlands.

RPA 901 - ALLEVIATE SOIL, WATER, AND AIR POLLUTION

Chemicals in forest management--do they contaminate the forest environment? Picloram, a potent herbicide, contaminated stream water for about one year after pellets were applied to a chaparral watershed in central Arizona. Picloram, also known as Tordon, is very resistant to decomposition by soil micro-organisms and is, therefore, highly persistent. It moves into stream water in overland flow or by leaching through the soil. The herbicide presents little hazard to any form of animal life, but picloram-contaminated water cannot be used for irrigation or any other use where it would come in contact with plants.

Paraquat, a contact herbicide and defoliant, had no appreciable influence on microbial activities important to fertility, according to two investigations made in Oregon. As part of a research program involving the effect of economic chemicals on forest soil and water, the interaction of herbicides on soil micro-organisms is of great importance. If the micro-organisms are seriously affected, soil fertility will not be maintained. These findings reinforce our knowledge that careful use of approved herbicides results in little or not pollution of forest soil and water.

Publications - USDA and Cooperative Programs

RPA 107 - TECHNOLOGY OF WATERSHED CONSERVATION AND MANAGEMENT

Improvement of Water Supplies for Agriculture, Industries, and Municipalities by Watershed Management

Beattie, Byron. 1967. Harvesting the National Forest water crop. Paper presented at the 36th Annu. Conv. of the National Reclamation Ass., Honolulu.

Beattie, Byron. 1967. Increased water yields and improved timing of streamflow through manipulation of forest vegetation and snowpack management. Int. Conf. Water for Peace, Washington, D. C.

Berndt, H. W., and Fowler, W. B. 1968. Contribution of rime ice to winter water balance in upper-slope forests of eastern Washington. (Abstr.) NW. Sci. 42(1): 29-30.

Doty, Robert D., and Johnston, Robert S. 1967. A heating system for stream gaging stations. J. Soil and Water Conserv. 22(6): 251-252.

Dunford, E. G. 1967. Forests--users of water. Soc. Amer. Foresters Proc. 1966: 146-150.

Dunford, E. G. 1967. Techniques in grassland watershed research. XIV. IUFRO-Congress Proc. Sect. 11: 444-462.

Essington, Edward H., and Smith, James L. 1967. Snow evaporation reduction: Migration of evaporation suppressants through snow. Amer. Nuclear Soc. Trans. 10(1): 77.

Fredriksen, Richard L. 1967. Three types of stream gaging instruments for small watersheds. Chapter: Stream Gages Artificial. Barometer Watershed Instrum. Work Conf. Proc. 1966. 11 pp.

Garcia, R. M., and Pase, C. P. 1967. Moisture retention capacity of litter under two Arizona chaparral communities. U.S.D.A. Forest Serv. Res. Note RM-85, 2 pp., illus.

Gary, Howard L. 1967. Density variation in a snowpack of northern New Mexico. 35th Annu. Western Snow Conf. Proc. 1967: 6-10, illus.

Gary, Howard L., and Coltharp, George B. 1967. Snow accumulation and disappearance by aspect and vegetation type in the Santa Fe Basin, New Mexico. U.S.D.A. Forest Serv. Res. Note RM-93, 11 pp., illus.

Gifford, Gerald F. 1967. The influence of growth media, temperatures, and light intensities on aspen root and top growth. U.S.D.A. Forest Serv. Res. Note INT-67, 4 pp.

Goldberg, Irving, MacGillivray, Norman A., and Ziemer, Robert R. 1967. Effects of neutron source type on soil moisture measurement. Amer. Nuclear Soc. Trans. 10(1): 20-21.

Goodell, B. C., Watt, J. P. C., and Zorich, T. M. 1967. Streamflow volumes and hydrographs by fluorescent dyes. XIV. IUFRO-Congress Proc. Sect. 11: 325-348, illus.

Haupt, Harold F., and Jeffers, Bud L. 1967. A system for automatically recording weight changes in sapling trees. U.S.D.A. Forest Serv. Res. Note INT-71, 4 pp., illus.

Helvey, J. D. 1967. Interception by eastern white pine. Water Resources Res. 3(3): 723-729.

Herring, H. G. 1968. Soil-moisture depletion by a central Washington lodgepole pine stand. NW. Sci. 42(1): 1-4, illus.

Hoover, Marvin D. 1967. Forests--where the waterflow starts. U.S. Dep. Agr. Yearbook 1967: 77-79.

Knipling, Edward B. 1967. Effect of leaf aging on water deficit-water potential relationships of dogwood leaves growing in two environments. Physiol. Plant. 20: 65-72, illus.

Knipling, Edward B. 1967. Measurement of leaf water potential by the dye method. Ecology 48(6): 1038-1041, illus.

Knipling, Edward B., and Kramer, Paul J. 1967. Comparison of the dye method with the thermocouple psychrometer for measuring leaf water potentials. Plant Physiol. 42(10): 1315-1320, illus.

Lawson, Edwin R. 1967. Throughfall and stemflow in a pine-hardwood stand in the Ouachita Mountains of Arkansas. Water Resources Res. 3(3): 731-735.

Leaf, Charles F. 1967. Areal extent of snow cover in relation to streamflow in central Colorado. Int. Hydrol. Symp. Proc. 1: 157-163, illus.

Leaf, Albert L., and Leonard, Raymond E. 1967. Forest fertilization, irrigation, and environment. S. Lumberman 215(2680): 163-165.

Leaf, Albert L., and Leonard, Raymond E. 1967. Measurement of environmental characteristics of a forest stand. XIV. IUFRO-Congress Proc. Sect. 21: 282-297.

Lopushinsky, William. 1968. Stomatal response of conifer seedlings to leaf water stress. (Abstr.) NW. Sci. 42(1): 38.

Lull, Howard W. 1967. Factors influencing water production from forested watersheds. Univ. Mass. Coop. Ext. Serv. Publ. 446: 2-7, illus.

Lull, Howard W. 1967. How our cities meet their water needs. U.S. Dep. Agr. Yearbook 1967: 104-109, illus.

Lull, Howard W., and Anderson, Henry W. 1967. Important watershed characteristics affecting water yield, flood peaks, and erosion and sedimentation and the basic data needed for prediction. Int. Conf. Water for Peace Proc. 1967, 8 pp.

Lull, Howard W., and Reinhart, Kenneth G. 1967. Increasing water yield in the Northeast by management of forested watersheds. U.S.D.A. Forest Serv. Res. Pap. NE-66, 45 pp., illus.

Lull, Howard W., and Reigner, Irvin C. 1967. Radiation measurements by various instruements in the open and in the forest. U.S.D.A. Forest Serv. Res. Pap. NE-84, 21 pp., illus.

Megahan, W. F., Meiman, J.R., and Goodell, B. C. 1967. Net allwave radiation as an index of natural snowmelt and snowmelt accelerated with albedo reducing materials. Int. Hydrol. Symp. Proc. 1: 149-156, illus.

Orr, Howard K. 1968. Soil-moisture trends after thinning and clearcutting in a second-growth ponderosa pine stand in the Black Hills. U.S.D.A. Forest Serv. Res. Note RM-99, 8 pp., illus.

Pase, Charles P. 1967. Helicopter-applied herbicides control shrub live oak and birchleaf mountainmahogany. U.S.D.A. Forest Serv. Res. Note RM-84, 4 pp., illus.

Pase, C. P., and Fogel, Martin M. 1967. Increasing water yield from forest, chaparral, and desert shrub in Arizona. Int.Conf. Water for Peace Proc.

Pase, C. P., Ingebo, P. A., Davis, E. A., and McCulloch, C. Y. 1967. Improving water yield and game habitat by chemical control of chaparral. XIV. IUFRO-Congress Proc. Sect. 11: 463-486, illus.

Patric, J. H. 1967. Evaporation and transpiration. Amer. Geophys. Union Trans. 48(2): 701-707.

Payne, Burnett H. 1967. Surveying the potential for water yield increase in the Pacific Southwest. 11th Annu. Ariz. Watershed Symp. 1967, 9 pp.

Price, Raymond. 1967. Possibilities of increasing streamflow from forest and range watersheds by manipulating the vegetative cover--the Beaver Creek pilot watershed evaluation study. XIV. IUFRO-Congress Proc. Sect. 11: 487-504.

Reigner, Irvin C. 1967. Effect of recreation on water quality. Univ. Mass. Coop. Ext. Serv. Publ. 446: 49-55.

Reigner, Irvin C. 1967. Review of: The hydrological role of forests by A. A. Molchanov (1963). Forest Sci. 13(1): 54.

Reigner, Irvin C., and Ningard, Louis G. 1967. Baltimore's watersheds: An example of integrated land use. J. Amer. Water Works Ass. 59(11): 1469-1477, illus.

Reinhart, Kenneth G. 1967. Increasing water production through manipulation of vegetation. Univ. Mass. Coop. Ext. Serv. Publ. 446: 17-21, illus.

Rogerson, T. L., and Byrnes, W. R. 1968. Net rainfall under hardwoods and red pine in central Pennsylvania. Water Resources Res. 4(1): 55-57, illus.

Rothacher, Jack. 1968. Influence of forest management practices on yield and quality of water. In Water and Environmental Quality, Seminar WR 008.67, Water Resources Res. Inst., Oreg. State Univ 1967: 25-31.

Rothacher, Jack, Dyrness, C. T., and Fredriksen, Richard L. 1967. Hydrologic and related characteristics of three small watersheds in the Oregon Cascades. U.S.D.A. Forest Serv. Pacific Northwest Forest and Range Exp. Sta., 54 pp., illus.

Sartz, Richard S. 1967. Winter thaws can raise ground water levels in Driftless Area. U.S.D.A. Forest Serv. Res. Note NC-35, 2 pp., illus.

Satterlund, Donald R., and Haupt, Harold F. 1967. Snow catch by conifer crowns. Water Resources Res. 3(4): 1035-1039, illus.

Smith, James L. 1967. Instrumentation for snow gaging--yesterday, today, and tomorrow. Isotopes and Radiation Tech. 4(3): 227-237.

Smith, James L. 1967. Use of nuclear techniques in snow and related watershed management. Amer. Nuclear Soc. Trans. 10(1): 78.

Sopper, W. E., and Lull, H. W. 1967. An evaluation of streamflow timing from small watersheds in Northeastern United States. XIV. IUFRO-Congress Proc. Sect. 11: 281-297.

Storey, Herbert C., and Reigner, Irvin C. 1967. Forests--national supplies and demands for water. Soc. Amer. Foresters Proc. 1966: 143-146.

Sturges, David L. 1968. Evapotranspiration at a Wyoming mountain bog. J. Soil and Water Conserv. 23(1): 23-25, illus.

Sturges, David L. 1967. Water quality as affected by a Wyoming mountain bog. Water Resources Res. 3(4): 1085-1089, illus.

Swanson, Robert H. 1967. Improving tree transpiration estimates based on heat pulse velocity measurements. XIV. IUFRO-Congress Proc. Sect. 11: 252-263.

Tabler, Ronald D. 1968. Soil-moisture response to spraying big sagebrush with 2,4-D. J. Range Manage. 21(1): 12-15, illus.

Tew, Ronald K. 1967. Soil moisture depletion by aspen in central Utah. U.S.D.A. Forest Serv. Res. Note INT-73.

Tew, Ronald K. 1967. Soil moisture depletion by Gambel oak in central Utah. U.S.D.A. Forest Serv. Res. Note INT-74.

Urie, Dean H. 1966. Forest cover in relation to water yields on outwash sand soils. Pap. Mich. Acad. Sci., Arts, and Letters (1965) 51: 3-11.

Wallis, James R. 1967. When is it safe to extend a prediction equation--an answer based upon factor and discriminant function analysis. Water Resources Res. 3(2): 375-384, illus.

Wooldridge, David D. 1967. Water transport in soils and streams. In Transport Phenomena in Atmospheric and Ecological Systems. Amer. Soc. Mech. Eng. Proc. 1967: 3-20, illus.

Ziemer, R. R., Goldberg, I., and MacGillivray, N. A. 1967. Measuring moisture near soil surface . . . minor differences due to neutron source type. U.S.D.A. Forest Serv. Res. Note PSW-158, 6 pp., illus.

Protection and Wise Stewardship of Forest Soil and Water Resources

Anderson, Henry W. 1967. Erosion and sedimentation. Amer. Geophys. Union Trans. 48(2): 697-700.

Dyrness, C. T. 1967. Mass soil movements in the H. J. Andrews Experimental Forest. U.S.D.A. Forest Serv. Res. Pap. PNW-42, 12 pp., illus.

Dyrness, C. T. 1967. Soil surface conditions following skyline logging. U.S.D.A. Forest Serv. Res. Note PNW-55, 8 pp., illus.

Glymph, Louis M., and Storey, Herbert C. 1966. Sediment--Its consequences and control. Amer. Ass. Advance. Sci. Meeting Proc. Agr. and Quality of Our Environment Symp. 1966: 205-220.

Hornbeck, James. 1967. Clearcutting and the erosion hazard. N. Logger 16(4): 14, 15, 38, 39, 48, illus.

Hornbeck, James W. 1968. Protecting water quality during and after clearcutting. J. Soil and Water Conserv. 23(1): 19-20, illus.

Kojan, Eugene. 1967. Mechanics and rates of natural soil creep. Fifth Annu. Eng. Geol. and Soils Eng. Symp. Proc., Idaho Dep. Highways, Univ. Idaho 1967: 233-253.

Levno, Al, and Rothacher, Jack. 1967. Increases in maximum stream temperatures after logging in old-growth Douglas-fir watersheds. U.S.D.A. Forest Serv. Res. Note PNW-65, 12 pp., illus.

McDonough, W. T., and Tew, R. K. 1968. Inhibitors of germination and growth from red elderberry: A laboratory evaluation. U.S.D.A. Forest Serv. Res. Note INT-72, 7 pp.

Nelson, T. C. 1967. Limitations on timber harvesting on erosive sites. Harvesting Pine Plantations on Erosive Soils Conf. Proc. 1967: 26-30.

Patric, James H. 1967. Frost depth in forest soils near Juneau, Alaska. U.S.D.A. Forest Serv. Res. Note PNW-60, 7 pp.

Patric, J. H., and Swanston, D. N. 1968. Hydrology of a slide-prone glacial till soil in southeast Alaska. J. Forest. 66(1): 62-66, illus.

Pierce, Robert S. 1967. Water-quality problems related to timber culture and harvesting. Univ. Mass. Coop. Ext. Serv. Publ. 446: 45-48.

Sartz, Richard S., and Curtis, Willie R. 1967. Simple sediment sampler for flumes. Agr. Eng. 48(4): 224, illus.

Swanston, Douglas N. 1967. Debris avalanching in thin soils derived from bedrock. U.S.D.A. Forest Serv. Res. Note PNW-64, 7 pp., illus.

Swanston, Douglas N. 1967. Soil-water piezometry in a southeast Alaska landslide area. U.S.D.A. Forest Serv. Res. Note PNW-68, 17 pp., illus.

Urie, Dean H. 1967. Waterline erosion control essential to streambank rehabilitation. U.S.D.A. Forest Serv. Res. Note NC-29, 2 pp.

Ursic, S. J. 1967. The Yazoo-Little Tallahatchie plantations and their role in watershed protection. Harvesting Pine Plantations on Erosive Soils Conf. Proc. 1967: 16-20.

Walkotten, William J., and Patric, James H. 1967. Elevation effects on rainfall near Hollis, Alaska. U.S.D.A. Forest Serv. Res. Note PNW-53, 8 pp., illus.

Williston, Hamlin L. 1967. Thinning desirable in loblolly pine plantations in west Tennessee. U.S.D.A. Forest Serv. Res. Note SO-61, 7 pp., illus.

Williston, H. L. 1967. Yields from Yazoo-Little Tallahatchie plantations. Harvesting Pine Plantations on Erosive Soils Conf. Proc. 1967: 21-25.

Williston, Hamlin L., and Dickerson, Bernard P. 1968. Influence of site and stand density on loblolly pine yield. Forest Farmer 27(6): 10-11, illus.

Yamamoto, Teruo, and Anderson, H. W. 1967. Erodibility indices for wildland soils of Oahu, Hawaii as related to soil forming factors. Water Resources Res. 3(3): 785-798.

Reduction of Human and Economic Loss From Floods

DeBano, L. F., Osborn, J., Krammes, J. S., and Letey, J. 1967. Soil wettability and wetting agents . . . our current knowledge of the problem. U.S.D.A. Forest Serv. Res. Pap. PSW-43, 13 pp., illus.

Krammes, J. S., and DeBano, L.F. 1967. Leachability of a wetting agent treatment for water-resistant soils. Soil Sci. Soc. Amer. Proc. 31(5): 709-711, illus.

Osborn, J., Letey, J., DeBano, L. F., and Terry, Earl. 1967. Seed germination and establishment as affected by nonwettable soils and wetting agents. Ecology 48: 494-497.

Sartz, Richard S. 1967. Annual soil temperature waves at four depths in southwestern Wisconsin. U.S.D.A. Forest Serv. Res. Note NC-32, 2 pp., illus.

Sartz, Richard S. 1967. A test of three indirect methods of measuring depth of frost. Soil Sci. 104(4): 273-278, illus.

Restoration of Soil Stability, Natural Beauty, and Income Opportunity

Aldon, Earl F., and Garcia, George. 1967. Summer deferred grazing can improve deteriorated semidesert ranges. U.S.D.A. Forest Serv. Res. Note RM-95, 3 pp., illus.

Copple, R. F., and Pase, C. P. 1967. A vegetative key to some common Arizona range grasses. U.S.D.A. Forest Serv. Res. Pap. RM-27, 72 pp., illus.

Covell, R. R., and McClurkin, D. C. 1967. Site index of loblolly pine on Ruston soils in the Southern Coastal Plain. J. Forest. 65(4): 263-264, illus.

Curtis, Willie R. 1967. Hydrology. In Kentucky Dep. Natural Resources Strip Mining Symp. Proc. 3 pp.

Curtis, Willie R., and Tolsted, David N. 1967. Chart holder uses old typewriter parts. Agr. Eng. 48(3): 154-155.

Davis, Grant. 1967. Hydrology of contour stip mines in the Appalachian region of the United States. XIV. IUFRO-Congress Proc. Sect. 11: 420-443, illus.

Davis, Grant. 1967. Revegetation. In Kentucky Dep. Natural Resources Strip Mining Symp. Proc. 3 pp.

Duffy, Paul D., and McClurkin, D. C. 1967. Stabilizing steep gully banks with excelsior mulch and loblolly pine. J. Soil and Water Conserv. 22(2): 70-71.

Dyrness, C. T. 1967. Grass-legume mixtures for roadside soil stabilization. U.S.D.A. Forest Serv. Res. Note PNW-71, 19 pp., illus.

Knipe, O. D. 1968. Effects of soil moisture stress on germination of alkali sacaton, galleta, and blue grama. J. Range Manage. 21(1): 3-4, illus.

Knipe, O. D. 1967. Influence of temperature on the germination of some range grasses. J. Range Manage. 20(5): 298-299.

Lane, Richard D. 1967. Cooperative strip mine research. In Kentucky Dep. Natural Resources Strip Mining Symp. Proc. 2 pp.

Mader, Donald L., and Lull, Howard W. 1968. Depth, weight, and water storage of the forest floor in white pine stands in Massachusetts. U.S.D.A Forest Serv. Res. Pap. NE-109.

McClurkin, D. C., and Ahlrich, V. E. 1967. Longfingergrass covers bare sites quickly. Crops and Soils 20(3): 18-19, illus.

McClurkin, Iola T., and McClurkin, D. C. 1967. Cytochemical demonstration of a sodium-activated and a potassium-activated adenosine triphosphatase in loblolly pine seedling root tips. Plant Physiol. 42(8): 1103-1110.

Plass, William T. 1967. Land disturbances from strip-mining in eastern Kentucky. 2. Princess Coal Reserve District. U.S.D.A. Forest Serv. Res. Note NE-55, 8 pp., illus.

Plass, William T. 1967. Land disturbances from strip-mining in eastern Kentucky. 3. Licking River Coal Reserve District. U.S.D.A. Forest Serv. Res. Note NE-68, 6 pp., illus.

Plass, William T. 1967. Land disturbances from strip-mining in eastern Kentucky. 4. Big Sandy Coal Reserve District. U.S.D.A. Forest Serv. Res. Note NE-69, 7 pp., illus.

Plass, William T. 1967. Land disturbances from strip-mining in eastern Kentucky. 5. Hazard Coal Reserve District. U.S.D.A. Forest Serv. Res. Note NE-71, 7 pp., illus.

Plass, William T. 1967. Land disturbances from strip-mining in eastern Kentucky. 6. Southwestern Coal Reserve District. U.S.D.A. Forest Serv. Res. Note NE-72, 8 pp., illus.

Plass, William T. 1967. Review-transactions of the American Philosophical Society, Pt. 1. Plant colonization studies on black waste from anthracite mining in Pennsylvania. (J. R. Schramm). J. Forestry 64: 820.

Plass, William T. 1967. Survey of eastern Kentucky. In Kentucky Dep. Natural Resources Strip Mining Symp. Proc. 6 pp.

Plass, William T., and Burton, James D. 1967. Pulpwood production potential on strip-mined land in the South. J. Soil and Water Conserv. 22(6): 235-238, illus.

Striffler, W. D. 1967. Restoration of open-cast sites in Great Britain. J. Soil and Water Conserv. 22(3): 101-103, illus.

Ursic, S. J., and Biesterfeldt, R. C. 1967. It pays to delay pine planting. Progr. Farmer, Georgia-Alabama-Florida edition 82(12): 28C, illus.

Ursic, S. J., Williston, H. L., and Burns, R. M. 1967. Late planting improves survival. Forest Farmer XXVI(9): 6-8, 16, 18.

Van Dyne, G. M., and Vogel, W. G. 1967. Relation of Selaginella densa to site, grazing, and climate. Ecology 48(3): 438-444.

Williams, George P. 1967. Roads, slides, and check dams. In Kentucky Dep. Natural Resources Strip Mining Symp. Proc. 4 pp.

Williston, Hamlin L. 1967. Clay slurry root dip impairs survival of loblolly pine seedlings in Mississippi. Tree Planters' Notes 18(4): 28-30, illus.

Williston, Hamlin L. 1967. Growth of pine planted for erosion control in north Mississippi. U.S.D.A. Forest Serv. Res. Note SO-67, 4 pp., illus.

Williston, Hamlin L. 1967. Improving loblolly pine survival in roadbank stabilization. Tree Planters' Notes 18(3): 18-20, illus.

RPA 105 - CONSERVATION AND EFFICIENT USE OF WATER FOR AGRICULTURE

Anderson, Henry W. 1967. General report. Symp. subject: New ideas and scientific methods in stochastic (statistical) hydrology. Int. Hydrol. Symp. Proc. 1967(2): 322-335.

Anderson, Henry W. 1967. Snow accumulation as related to meteorological, topographic, and forest variables in central Sierra Nevada of California. Int. Ass. Sci. Hydrol. Publ. 78: 215-224, illus.

Bay, Roger R. 1967. Ground water and vegetation in two peat bogs in northern Minnesota. Ecology 48(2): 308-310.

Bay, Roger R. 1967. Techniques of hydrologic research in forested peatlands. XIV. IUFRO-Congress Proc. Sect. 11: 400-415.

Bormann, F. H., Likens, G. E., Fisher, D. W., and Pierce, R. S. 1968. Nutrient loss accelerated by clear-cutting of a forest ecosystem. Science 159: 882-884, illus.

Klawitter, Ralph A. 1967. Water management in coastal plain woodlands. S. Lumberman 215(2680): 175-177, illus.

Likens, G. E., Bormann, F. H., Johnson, N. M., and Pierce, R. S. 1967. The calcium, magnesium, potassium and sodium budgets for a small forested ecosystem. Ecology 48(5): 772-785, illus.

Rice, Raymond M. 1967. Multivariate methods useful in hydrology. Int. Hydrol. Symp. Proc. 1967: 471-478, illus.

Stoeckeler, J. H. 1967. Size and placement of metal culverts critical on peatland woods roads. U.S.D.A. Forest Serv. Res. Note NC-37, 3 pp.

Rogerson, T. L., and Ursic, S. J. 1967. New neutron probe system speeds logging of soil water profiles. XIV. IUFRO-Congress Proc. Sect. 11: 416-419, illus.

Ursic, S. J. 1967. Improved standards for neutron soil water meters. Soil Sci. 104(5): 323-325.

Ursic, S. J., and Popham, T. W. 1967. Using runoff events to calibrate small forested catchments. XIV. IUFRO-Congress Proc. Sect. 11: 319-324.

Young, Cortland E., Jr. 1967. Streamflow--important factor in forest management. S. Lumberman 215(2680): 109-110, illus.

RPA 901 - ALLEVIATE SOIL, WATER, AND AIR POLLUTION

Anonymous. 1967. Cut stream contamination with careful chemical brush control. Oregon's Agricultural Progress. Oreg. State Univ. 14(1): 10-11.

Brannock, L. Douglas, and Freed, V. H. 1967. Internal instrumental clean-up for gas chromatographic analysis of pesticide residues. (Abstr.) Amer. Chem. Soc., NW. Regional Meeting, Abstr. of Tech. Papers in 1967: 6.

Norris, L. A. 1967. Chemical brush control and herbicide residues in the forest environment. In Herbicide and Vegetation Manage. Symp. Proc., Oreg. State Univ. 1967: 103-123.

Bollen, Walter B., Chen, Chi-Sin, Lu, Kuo C., and Tarrant, Robert F. 1967. Influence of red alder on fertility of a forest soil--microbial and chemical effects. Forest Res. Lab., Oreg. State Univ. Res. Bull. 12, 61 pp., illus.

Davis, E. A., Ingebo, P. A., and Pase, C. P. 1968. Effect of a watershed treatment with picloram on water quality. U.S.D.A. Forest Serv. Res. Note RM-100, 4 pp., illus.

Sturges, David L., and Sundin, Robert E. 1968. Gross alpha and beta radiation in waters at a Wyoming mountain bog. Water Resources Res. 4(1): 159-162, illus.

Tarrant, R. F. 1968. Forest soil improvement through growing red alder (Alnus rubra Bong.) in Pacific Northwestern United States. 8th Int. Congr. Soil Sci. Trans., Bucharest, Romania, 1964, V: 1029-1043.

Tarrant, Robert F. 1968. Influence of introduced chemicals on forest water quality. In Water and Environmental Quality, Seminar WR 008.67, Water Resources Res. Inst., Oreg. State Univ. 1967: 33-46.

Tarrant, Robert F. 1967. Insecticide residues in Oregon's forests. In Pest Control Progress and Problems in Oregon. Oreg. Interagency Pesticide Council Conf. Proc. 1966: 30.

Tarrant, Robert F. 1967. Pesticides in forest waters--symptom of a growing problem. Soc. Amer. Foresters Proc. 1966: 159-163.

Tarrant, R. F., Lu, K. C., Bollen, W. B., and Chen, C. S. 1967. Chemical composition of throughfall and stemflow in three coastal Oregon forest types. (Abstr.) Amer. Soc. Agron. Agron. Abstr. p. 137.

Tarrant, Robert F., and Norris, Logan A. 1967. Residues of herbicides and diesel oil carriers in forest waters: A review. In Herbicides and Vegetation Manage. Symp. Proc., Oreg. State Univ. 1967: 81-88.

Tu, C. M., and Bollen, W. B. 1968. Effect of paraquat on microbial activities in soils. Weed Res. 8: 28-37.

Tu, C.M., and Bollen, W. B. 1968. Interaction between paraquat and microbes in soils. Weed Res. 8: 38-45.

FOREST RECREATION RESEARCH

(RPA 902 - FORESTLAND RECREATION)

USDA and Cooperative Program

Location of Intramural Work	Scientist Man-years FY 1968
California	3.4
Florida	1.2
Michigan	2.3
Minnesota	3.5
Montana	1.3
New York	3.0
North Carolina	3.0
Utah	1.5
Washington	2.5
Total	21.7

Intramural program is supplemented by extramural support representing (a) 0 SMY's at State Agricultural Experiment Stations, (b) 2 SMY's at other institutions and (c) P. L. 480 funds in 0 countries representing $0 U.S. dollars equivalent.

Problems and Objectives

Outdoor recreation is a major industry, a major use of land and water resources, a major leisure-time activity, and a major opportunity for aesthetic and economic enhancement of rural America. The task of forest recreation research is to identify recreation needs and future demands, and provide information which will guide investment, development and management of public and private forest lands for recreation and the enhancement of natural beauty.

Specifically, the research objectives are to (1) characterize recreation users and use on public and private forest lands in order to better evaluate recreation needs, trends, and future demand, (2) determine the criteria for profitable income-producing recreation enterprises and their job producing opportunities, (3) develop and test design concepts and principles to guide the use, management, and enhancement of forest landscapes, (4) provide criteria to select, develop, and maintain heavily used forest recreation sites, and (5) provide a better factual basis for policy and management of wilderness and multipurpose forest lands through ecological and socioeconomic studies.

Progress - USDA and Cooperative Program

Advice for the private sector gained through experience. A new publication of case studies of 5 outdoor recreation enterprises in Ohio is providing money making and money saving suggestions for active and would-be operators to consider:

--Each of the 5 Ohio operators reported he would have developed his enterprise differently if he could do it again.

--One said he would have bought more land initially. He is now trying to acquire adjacent land but he must pay far more than he would have had to in the beginning.

--Another said he would begin with the most modern facilities available rather than try to get along with merely adequate ones.

--The operator of a fishing enterprise said he would build a smaller lake with a more regular shoreline. Policing the area and cleaning up litter cost too much with the larger lake.

--One operator said he would have developed more facilities for daily patrons than for overnight guests. He would also pay much more attention to facility location to better avoid traffic congestion. He would also adjust fee systems whereby patrons would pay only for those facilities they used.

--Two operators said they would make more and earlier use of professional advertising agencies to build up attendance.

The operators, of course, are pleased with their several "right" decisions:

--All operators were very strict about the appearance of both employees and facilities. It was common practice to scrub picnic tables with soap and water at the end of each day, to thoroughly clean toilets during and after each day, and to have at least one neatly dressed person constantly policing the area for unsightly litter. One operator repaints all of his facilities before opening for business each spring.

--None of the operators posted "do's" and "don't's." Each maintained only those regulations necessary for the visitors' enjoyment, convenience, and safety. The objective was to make each patron feel unrestricted while using the facilities provided.

--All operators are advertising to stimulate business. Three reported using spot commercials over radio; two use a professional advertising agency; two place ads in Sunday newspapers in large Ohio cities; one uses brochures; and one sends annual newsletters to previous customers; all agreed that a satisfied customer was their most effective promotion agent.

Some more keys to profitable outdoor recreation enterprises. A main ingredient for a successful outdoor recreation enterprise--satisfied customers--was verified in a New Hampshire study. Over 300 campers were asked to evaluate their visit satisfaction on a four point scale: "Highly Satisfied," "Well Satisfied," "Satisfied," and "Dissatisfied." The most we can say about the scale is that it was meaningful to the campers, and that the people at one end of the scale were more pleased with their visit than those at the other end--and this meant dollars for the operators. On the average, campers who were dissatisfied reduced their planned visit by one full day. Campers who were more than satisfied stayed an extra day and, of course, paid an additional campsite rental fee. Now, here are some of the things that seem to have an influence on satisfaction:

--Direct increases in campground size (number of campsites), campground age (in years), and investment (in dollars), are accompanied by direct increases in visit length, visit frequency, and percentage of visitors who plan to return in the future.

--The presence of a swimming and boating attraction at or near the campground is associated with longer and more frequent visits, and more numerous plans to return.

--An increase in the number of activities engaged in at the campground is accompanied by a slight increase in camper satisfaction.

--The location of a campground is important to success. In a regional comparison, the less successful ventures were mostly in a region remote from major metropolitan centers, where lakes were scarce, competition (both public and private) was keen, and the camping season was shorter.

--A preference for private campgrounds, as well as a lack of preference for public campgrounds, accompanies longer and more frequent visits, and a greater incidence of intentions to return.

--Highly mobile camping equipment was generally accompanied by shorter but more frequent visits; and the incidence of mobile equipment was 100 percent higher at private campgrounds than at public ones.

--Trip plans are apparently fairly flexible, judging from the increase in actual over planned visit lengths. A surprising number of campers indicated that they had planned a 2- or 3-day visit and ended up staying a week or more.

--It is apparently impossible to identify"primary reasons for camping" such as economy, enjoyment of nature, or social contacts. Camping is a mixed bag of interests, including some apparently contradictory ones like "peace and quiet" along with the "opportunity to meet and visit with other campers." The incidence of past visits was almost invariably associated with longer current visits, and with a very high incidence of intentions to return. Past visits were also more common among private campground patrons.

--Campers who belonged to camping organizations were found to be twice as prevalent at private campgrounds as at public areas.

--The majority of successful campgrounds did not have camping owners whereas the majority of unsuccessful campgrounds were run by managers who were themselves campers.

--The majority of successful campgrounds had well-developed advance-reservation systems. And visits were longer at campgrounds with reservation systems than at those without them.

--The general finding that campground size accompanies success may indicate part-time management as well as fewer attractions and activities at many of the smaller enterprises.

--Successful campground owners were more than twice as likely to belong to a campground owner's association.

Campground owners can cash in on camper differences. A New England study shows that campers at privately owned campgrounds differed significantly from campers at State Park and National Forest campgrounds, and those campground owners who recognize and accommodate to these differences stand to make a better profit.

--Over twice as many commercial campground visitors: (1) own, rent, or have the use of a camping trailer and demand highly developed facilities, (2) belong to a camping or outdoor organization, and (3) select their campground on the recommendation of others.

--Nearly twice as many commercial campground users tend to revisit campgrounds rather than try new ones.

--Significantly more commercial campground visitors: (1) go on a vacation trip of at least 2 weeks duration and (2) camp for 20 days or more per year.

Wilderness Users - their characteristics and preferences. The results of a study of wilderness users in the Pacific Northwest show that:

--About 50 percent of the wilderness visits were by small groups of close friends.

--Over 70 percent of all wilderness users took their first wilderness trip before they were 15 years old.

--Almost all of the wilderness users were of high social class in terms of education, income, and occupation. This suggests that as children of current wilderness users mature and initiate their children to this type of recreation, and as more of the population enters the social strata characteristic of these users, wilderness visitation will increase.

--Less than 30 percent of all wilderness users belonged to an outdoor club or conservation group, but this minority represented 218 outdoor and conservation organizations.

--Many of the wilderness users were "purist" in that they strongly reject the use of helicopters, surfacing trails to combat dust and mud, any toilet facilities, rustic tables, corrals, or artificial revegetation of areas denuded by fire, insects, or disease.

--Many other wilderness users, however, were not so purist and preferred comfort and convenience developments beyond the terms of the Wilderness Act, such as hiker shelters, tables, concrete fireplaces, and surfaced trails.

A related study shows that Wilderness use since 1946 has grown three times as fast as use of developed campgrounds. There is little doubt that future wilderness visits may soon exceed both the physical and social carrying capacity of classified wilderness, yet a large percentage of the users will not be seeking wilderness in the pure and precise sense defined in the Wilderness Act. This suggests a need for additional back-country areas to be managed as semiwilderness, thereby reducing the visitor pressure on classified wilderness.

Camping patterns vary with differences in family age and structure. A study of remote (wilderness type) and easy access (roadside) campgrounds in Oregon (1) tells us more as to who is making specific demands for recreation, what processes helped shape the demands and (2) suggests several management implications:

--Campers included fewer families without children and more families with 2 or 3 children than the population from which they came.

--Parents with no children or young children were most likely to be back-country campers.

--Those with children 5 to 14 years old were most likely to be roadside campers, and those with grown children were most likely to be back-country campers. This suggests the need for adequately providing recreation outlets for very vigorous and active preteenagers such as playground equipment. The study further suggests a shift in recreation preference with advancement of the family life cycle.

--City dwellers were more likely to be campers than rural residents.

--Contrary to popular belief, wilderness campers were less likely to have long vacations than roadside campers.

--Those who did not begin to enjoy the out-of-doors until they were 19 were most likely to be easy access campers.

--The tendency for campers to continue and expand recreation patterns plus the fact that camping is a family activity suggests (as does the characteristics study described above) that a higher percentage of future camping populations will have primitive camping preferences.

Fee charges need better explanation. Public campground users on the Huron National Forest in Michigan were asked how they felt about paying the $7 national Golden Passport fee and the $1 daily additional fee for the campground in which they were camped. Most showed a willingness to pay for the $7 passport but many objected to the additional charge. The public simply doesn't like double charging.

Accurate use figures lead to better management. Efficient planning and management for outdoor recreation calls for reliable measurements of recreation use in terms of numbers of visitors and length of stay. Such measurements have been relatively simple for intensively used sites such as campgrounds or ski areas. Now, reliable procedures have been developed for estimating mass and dispersed types of recreation use on large areas. A sampling system to estimate mass and dispersed types of recreation use on an entire National Forest Ranger District (which totalled nearly 200,000 visitor-days in 1967) was pilot tested in California. Estimates of use were obtained within acceptable limits of accuracy for approximately 45 recreational activities on both public and privately owned land within the District's boundaries. With this information as a base, use estimates on an activity-by-activity basis can be inexpensively updated annually for several years based on formulae developed during the 1967 calibration period.

Help for the resource manager through knowledge of plant behavior under intensive recreation use. A Pennsylvania study shows the intensity of recreational use in a campground does not necessarily produce a direct reduction in the density of plants making up the ground cover. At first, the number of plant species present declined markedly, but on those sites where competition had been reduced the remaining species gained in density. Bluegrass, bent grass, path rush, and clover were all found to have good natural resistance to trampling. Under sustained trampling pressures, however, the normal growth form of many of the plants changed dramatically, and ground cover destruction was accelerated by the abrasive action of loose gravel, poor maintenance, stationary tables, and extended visits where camping equipment was not moved for long periods of time.

An inexpensive technique for evaluating mountain fishing streams. A major recreational activity and value of many western streams is sport fishing. Too often, however, there is a lack of knowledge on the extent of the stream resource and habitat conditions which influence fish productivity. A common procedure for evaluating a fishing stream is for an experienced biologist to walk along a stream and make observations and measurements. Such persons are expensive and in short supply. A Utah study provides a money saving alternative: Train subprofessional personnel to make objective measurements which can be evaluated by professional biologists. Precise, simple, and inexpensive methodology was devised for estimating stream length and width, surface area, pool area, riffle area, depth of streambed composition, vegetative cover of streambanks, and streambank stability. Measurements are taken on selected cross-stream transects at an average cost of $19 per mile of stream surveyed.

Publications - U.S.D.A. and Cooperative Program

Arnold, R. Keith, and Hopkins, Walter S. 1967. Scope of recreation research. XIV. IUFRO-Congress, München 1967 Papers, VII, Sect. 26: 1-13.

Bachman, Earl E. 1967. Recreational facilities . . . a personal history of their development in the National Forests of California. U.S.D.A. Forest Serv. Calif. Region, Pacific Southwest Forest and Range Exp. Sta., Berkeley, Calif., 52 pp., illus.

Beardsley, Wendell. 1967. Cost implications of camper and campground characteristics in central Colorado. U.S.D.A. Forest Serv. Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo., Res. Note RM-86, 7 pp., illus.

Burch, William R., Jr., and Wenger, Wiley D., Jr. 1967. The social characteristics of participants in three styles of family camping. U.S.D.A. Forest Serv. Pacific Northwest Forest and Range Exp. Sta., Portland, Ore., Res. Pap. PNW-48, 30 pp., illus.

Burke, Hubert D., Lewis, Glenn H., and Orr, Howard R. 1968. A method for classifying scenery from a roadway. Park Practice Guideline 22: 125-141, illus.

Cooper, Glenn A. 1968. Hardwood picnic tables can take it. Parks & Recreation III(5): 50-51, 72-74, illus.

Heinselman, Miron L. 1966. Vegetation in wilderness areas. Trends in Parks & Recreation 3(1): 23-27, illus.

Hendee, John Clare. 1967. Recreation clientele--the attributes of recreationists preferring different management agencies, car campgrounds or wilderness in the Pacific Northwest. Diss. Abstr. Vol. XXVIII, No. 5 (Ph. D. thesis, Univ. of Washington), 2 pp.

Herrington, Roscoe B., and Dunham, Donald K. 1967. A technique for sampling general fish habitat characteristics of streams. U.S.D.A. Forest Serv. Intermountain Forest and Range Exp. Sta., Ogden, Utah, Res. Pap. INT-41, 12 pp., illus.

Herrington, Roscoe B., and Tocher, S. Ross. 1967. Aerial photo techniques for a recreation inventory of mountain lakes and streams. U.S.D.A. Forest Serv. Intermountain Forest and Range Exp. Sta., Ogden, Utah, Res. Pap. INT-37, 21 pp., illus.

James, George A. 1967. Recreation use estimation on Forest Service lands in the United States. U.S.D.A. Forest Serv. Southeast. Forest Exp. Sta., Asheville, N.C., Res. Note SE-79, 8 pp., illus.

James, George A., and Cottrell, Richard L. 1968. To cut or not to cut. J. Forest. 66: 57-59, illus.

James, George A., and Harper, R. A. 1967. How much and what kind. Florida Wildlife 21(2): 18-19, illus.

James, George A., and Henley, Robert K. 1968. Sampling procedures for estimating mass and dispersed types of recreation use on large areas. U.S.D.A. Forest Serv. Southeast. Forest Exp. Sta., Asheville, N.C., Res. Pap. SE-31, 15 pp., illus.

James, George A., and Taylor, Gordon D. 1967. Recreation use estimation in the United States and Canada. XIV. IUFRO-Congress, München 1967 Papers, VII, Sect. 26: 14-29.

Jemison, George M. 1967. Impacts of recreation on the ecology of temperate North American forests. Int. Union for Conserv. of Nature, 10th Tech. Meeting Proc. and Papers, June 1966, Lucerne Part I. Ecological impact of recreation and tourism upon temperate environment--Sect. 2 B, IUCN Publications New Series No. 7 (1967), pp. 173-185.

King, David A. 1966. Activity patterns of campers. U.S.D.A. Forest Serv. N. Cent. Forest Exp. Sta., St. Paul, Minn., Res. Note NC-18, 3 pp.

King, David A. 1968. Socioeconomic variables related to campsite use. Forest Sci. 14(1): 45-54.

LaPage, Wilbur F. 1967. Camper characteristics differ at public and commercial campgrounds in New England. U.S.D.A. Forest Serv. Northeast. Forest Exp. Sta., Upper Darby, Pa., Res. Pap. NE-59, 8 pp., illus.

LaPage, Wilbur F. 1967. Review of: Economics of outdoor recreation, by Marion Clawson and Jack Knetsch (1966). Rural Sociol. 32: 478-479.

LaPage, Wilbur F. 1968. The role of customer satisfaction in managing commercial campgrounds. U.S.D.A. Forest Serv. Northeast. Forest Exp. Sta., Upper Darby, Pa., Res. Pap. NE-105, 23 pp., illus.

LaPage, Wilbur F. 1967. Some observations on campground trampling & ground cover response. U.S.D.A. Forest Serv. Northeast. Forest Exp. Sta., Upper Darby, Pa., Res. Pap. NE-68, 11 pp., illus.

LaPage, Wilbur F. 1967. The successful campground formula. Family Camping Area Manage. Conf. Proc. (Sponsored by Coop. Ext. N.Y. State in coop. with Campground Owners of N.Y.), Nov. 17-18, 1967, Cornell Univ., Ithaca, N.Y., 35-52, illus.

Lucas, Robert C. 1967. The changing recreational use of the Boundary Waters Canoe Area. U.S.D.A. Forest Serv. N. Cent. Forest Exp. Sta., St. Paul, Minn., Res. Note NC-42, 4 pp.

Lucas, Robert C. 1966. Research needs generated by new directions in forest policy. Soc. Amer. Forest. Proc., 1965, Detroit, Mich., 73-75.

Maddock, Stephen J., and Gehrken, George A. 1967. Are company hunting policies understood by hunters? Southern Lumberman, Christmans Issue 215 (2680): 195, 198, illus.

Maddock Stephen J., Gehrken, George A., and Guthrie, W. Alan. 1966. Outdoor recreation preferences of rural residents. Study shows hunting and fishing lead in popularity. Va. Wildlife XXVII(3): 20, illus.

Magill, Arthur W., and Leiser, Andrew T. 1967. New help for worn out campgrounds. Family Camping Leader 4(4): 16-18, illus.

Paine, Lee A. 1967. Effective tree hazard control on forested recreation sites . . . losses and protection costs evaluated. U.S.D.A. Forest Serv. Pacific Southwest Forest and Range Exp. Sta., Berkeley, Calif., Res. Note PSW-157, 8 pp., illus.

Paine, Lee A. 1967. Tree hazard control on recreation sites . . . estimating local budgets. U.S.D.A. Forest Serv. Pacific Southwest Forest and Range Exp. Sta., Berkeley, Calif., Res. Note PSW-160, 5 pp.

Ripley, Thomas H. 1966. Rehabilitation of forest recreation sites. Soc. Amer. Forest. Proc., 1965, Detroit, Mich., 35-36.

Shafer, Elwood L., Jr. 1968. The demand for water-oriented outdoor recreation. Parks & Recreation III(2): 22-25, 57, illus.

Shafer, Elwood L., Jr. 1967. Forest aesthetics--a focal point in multiple-use management and research. XIV. IUFRO-Congress, München 1967 Papers, VII, Sect. 26: 47-71, illus.

Shafer, Elwood L., Jr., and Hamilton, John F., Jr. 1967. A comparison of four survey techniques used in outdoor recreation research. U.S.D.A. Forest Serv. Northeast. Forest Exp. Sta., Upper Darby, Pa., Res. Pap. NE-86, 22 pp., illus.

Twiss, Robert H. 1967. Wildlife in the metropolitan landscape. Thirty-Second N. Amer. Wildlife and Resources Conf. Trans. 1967: 69-74.

Wagar, J. Alan. 1967. Simulated trampling as a technique in recreation research. XIV. IUFRO-Congress, München 1967 Papers VII, Sect. 26: 239-245, illus.

Wayt, William A., Acton, Robert W., and Whittaker, James C. 1968. A look at commercial recreation on small woodlands in Ohio. U.S.D.A. Forest Serv. Northeast. Forest Exp. Sta., Upper Darby, Pa., Res. Pap. NE-101, 11 pp., illus.

RANGE MANAGEMENT

USDA and Cooperative Program

Location of Intramural Work	Scientist Man-Years F.Y. 1968		
	Research Problem Area		Total
	110	112	
Arizona		5.0	5.0
California		4.0	4.0
Colorado	2.0	4.0	6.0
Florida		4.8	4.8
Idaho		1.4	1.4
Louisiana		3.0	3.0
Missouri		2.0	2.0
Montana		2.1	2.1
New Mexico		1.0	1.0
Oregon		4.0	4.0
Utah		4.7	4.7
Wyoming		1.0	1.0
Washington, D.C.	2.0		2.0
Total	4.0	37.0	41.0

Intramural program is supplemented by extramural support representing (a) 0.5 SMY's at State Agricultural Experiment Stations, (b) 0.2 SMY's at other U.S. institutions, and (c) P.L. 480 funds in 0 country representing 0 U.S. dollars equivalent (FY 1968).

Problems and Objectives

Rangeland in the United States is a 900-million-acre resource which benefits a large segment of rural and urban America through production of forage for livestock and wildlife, the attendant services and industries, husbandry of soil and water values, and human enjoyment achieved from its aesthetic qualities. On extensive areas, however, many ranges are far below their productive potential and in the western mountains especially watershed values have been impaired by injudicious use. Management of these lands is often complicated by a delicate balance of climate, vegetation, soils and topography. Furthermore, livestock grazing must be coordinated with other land uses. Consumer demands for a projected 2.8 million additional tons of beef by 1980 will be satisfied in large part by intensified application of past research coupled with findings from planned, new research.

Major objectives of the research are to:

1. Identify, measure and evaluate the forage resource efficiently.
2. Determine growth characteristics and requirements of the vegetation.
3. Develop optimum management systems for maximum production of forage and livestock.
4. Determine the effects of fire and other range improvement practices.
5. Ascertain the influence of rodents and other range pests as a basis for control.

Progress - USDA and Cooperative Programs

RPA 110 - APPRAISAL OF FOREST AND RANGE RESOURCES

A. Range Resource Evaluation

Ranchers, sportsmen, wildlife and range workers, and other ecologists and conservationists have needed a fieldbook to help identify Ozark plants and describe their usefulness to wildlife and range livestock. Plants typical of several geographic regions meet endemic species in the Ozarks to make field identification difficult. An illustrated book prepared to fill that need consists of keys for summer and winter plant identification and descriptions of selected plants, their distribution, site preference, general value for game animals and livestock, and poisonous properties.

Decision making for juniper control operations has been strengthened by the development of a useful mathematical equation. The response of herbage production following juniper (Juniperus sp.) removal and other overstory-understory relationships in the Southwest can be described by the equation $Y = H + A (1-e^{-bx})^{M}$. In the equation Y is herbage production in pounds per acre, X is canopy cover in percent, H and A are upper and lower asymptotes, respectively, of the canopy cover, e is the base of the natural logarithm, b is the regression coefficient and M adjusts the inflection point of the curve.

In other studies reliable estimates of foliage and fruit yields of Utah juniper (Juniperus osteosperma) were made easily and quickly from measurements of crown diameter. Prediction equations were greatly improved by placing the trees in crown classes (sparse, medium and dense). Yield tables developed are useful to field personnel in evaluating site potential and condition of native rangeland occupied by trees.

Interpretations of large-scale (1:640 - 1:4800) 70 mm. color and color infrared photography indicated the high resolution qualities of these films enables detection and identification of individual plants and other objects as small as 1 inch in diameter. Items such as cattle tracks, gopher casts and mounds, ant mounds and dead deer could easily be seen in the largest scale aerial photographs (1: 640 - 1:1200) with both film types. The employment of sophisticated aerial photography techniques improves identification and classification of plant communities, and other features of the range environment and may efficiently monitor changes in vegetation over time.

Where tall bluebell (Mertensia arizonica) is plentiful on mountain areas grazed by sheep and cattle, the range is usually in good condition. Studies in Utah show that by changing the grazing sequence of the range areas from one year to the next, bluebell can be maintained, thereby providing the range manager assurance that range condition is not deteriorating. A practical grazing system will avoid too heavily grazing ranges with bluebell, especially during late June and early July. Moderate grazing in early June and again after mid-July is not damaging.

Knowledge of the understory plants and development of efficient means to measure and characterize individuals and communities are essential to determine present condition and potential capacity of forest and related ranges for the production of livestock and wildlife. Progress is visible in the solution of problems through early recognition and evaluation of changes related to grazing use. These are especially pertinent for application of corrective management practices to maintain or improve the resource base.

RPA 112 - RANGE MANAGEMENT

A. Characteristics and Requirements of Range Plants

Grazing management practices are contingent upon sound, fundamantal information involving all facets of plant growth and the many physical and biotic factors of the environment. Most of the studies are problem-oriented but some are necessarily directed towards the underlying facts that define the many range ecosystems and their operational mechanisms. Past experience has shown such research yields the broad base for solution of practical management and improvement problems.

On mountain ranges in Montana, herbage removal by clipping which simulated grazing caused a conspicuous shift toward grasses in total herbage composition. Forbs were most sensitive to herbage removal just before or during flowering but grasses were harmed most from flowering to seed ripening. Clipping during early growth or after the foliage began to dry did not damage either the forbs or grasses appreciably. Total vegetation production decreased significantly only after 3 years of intensive clipping. Prior to this herbage removal did not offset the advantage of reduced competition. Recognition of relative sensitivity to herbage removal and aggressiveness of species in developing grazing systems can improve the productivity of these grasslands.

Each additional inch of summer rainfall on the Santa Rita Experimental Range near Tucson, Arizona, increased average perennial grass yields about 125 pounds per acre. One deep wetting of the soil in summer produced a conspicuous amount of perennial grass herbage due to their deeper root systems, but rarely produced grazable herbage from annual grasses. Surface soil moisture was rapidly depleted due to transpiration and high evaporation resulting from excessive soil temperatures. The amount and kind of forage that will be available for livestock is closely related to these environmental characteristics.

Grasslands, which are important for livestock and game in the Black Hills of South Dakota, are found as two major types: bluegrass and mixed prairie. Bluegrass range withstands grazing better than mixed prairie and total herbage production is higher. Moisture regime is an important single factor in determining the grassland type that will be found on a given site. The more moist sites are dominated by bluegrasses (Poa spp.) and the drier sites by prairie vegetation, mainly blue grama (Bouteloua gracilis), needle-and-thread (Stipa comata) and bluestem (Andropogon spp.). Forbs are more abundant on grazed bluegrass ranges than in exclosures but the reverse is true on the mixed prairie sites. Herbage production is similar on grazed and ungrazed bluegrass range but considerably greater on ungrazed mixed prairie than on its grazed counterparts.

Phenological information of Arizona fescue (Festuca arizonica) and mountain muhly (Muhlenbergia montana), two important range grasses in the ponderosa pine type, is useful: 1) in predicting when livestock grazing may begin, 2) as a guide to forage quality and 3) as an aid in designing a sound grazing system. Two growth periods occur in northern Arizona. Growth of Arizona fescue is greatest during May while mountain muhly growth occurs mainly during July and August. The rate of fescue growth is related to the precipitation falling in any previous month of the growing season up to July when flowering activity apparently is more important. Mountain muhly height growth was related to precipitation in July and August. Ranges dominated by fescue may be grazed earlier than muhly ranges. Where the species occur together management can favor both by moderate grazing an area early one year and late the next.

The energy relationships of alpine species in Wyoming aid in understanding the harsh ecosystems of these high elevation ranges which are valuable watersheds and often used for the production of grass-fat lambs. Gross energy of aboveground parts of eight alpine species in two sedge-hairgrass communities averaged 4.16 kcal/g dry weight during the summer months. The relatively high values found in alpine species permit rapid development and completion of the annual growth cycle in a short period.

Soil compaction from a heavy concentration of livestock on the Ashley National Forest in eastern Utah was overcome by providing a rest period after grazing. The heavy use did not subsequently interfere with water absorption of the soil and bulk densities of the surface 6 inches of soil of grazed plots were similar to those in ungrazed exclosures. With present systems of management such concentrations of animals frequently occur, but from these studies damage to important soil characteristics is minimal.

Lignin content of the forage is the major factor in the daily gain of sheep on crested wheatgrass pastures in Wyoming. This, plus number of animals and forage available/sheep/day, accounted for 77 percent of the variation in gain/sheep/day. Since the performance of the grazing animal depends largely upon the amount and digestibility of forage eaten, these factors bear strongly upon the economic success of the range operation.

Forage samples of 11 species were collected from a ponderosa pine range in northern Arizona to determine whether the digestibilities of individual forage species can be used to infer information about an animal's diet containing a mixture of the same species. Digestibilities of diet mixtures and of individual forage species were determined by the in vitro or artificial rumen technique which simulates natural digestion under laboratory conditions. It was learned that after adjustment for the relative proportions of a species in the range cattle diet, individual species digestibilities can be used to determine diet mixture digestibilities which are used in range forage evaluations.

In in vitro digestion studies of range forage the time interval from collection and preparation of samples and introduction of the rumen inoculum may be a week or longer. In this interval the activity of the inoculum may be different than it was when the forage was collected. However, forage samples from northern Arizona ponderosa pine ranges were digested with rumen inoculum collected following various delays after forage collection. Inoculum collected after a 6-week delay gave equivalent forage digestibility values as a 2-week delay; 10-week values were slightly lower but not significantly different from the 2-week samples. The 14-week samples could not be used to estimate range forage digestibility.

On mountain rangelands of the interior Northwest there is a predictable timing in decline of percent crude protein in the principal native forage plants that is reflected in a decline of cow weights and rate of gain of their calves from mid-August to October. Grasses were below the desired level generally after mid-July. Elk sedge (Carex geyeri), however, consistently maintained a protein level about 6 percent until late September and in some years until October 15. The amount of precipitation appeared to be the main factor determining crude protein content of herbage. Plants common to open grasslands produced regrowth in response to fall rains and protein levels increased above midsummer lows.

The removal of litter or "rough" appears to be the major cause of forage improvement of southern bluestem range; fire destroys it and grazing prevents it from accumulating. The effect of such treatment on forage quality and quantity on range was determined by burning and mechanical removal of herbage to simulate grazing. For two years following treatments neither yield nor nutrient content of herbage on burned plots differed from that on plots that were closely mowed and raked.

B. Livestock Grazing Practices

Actual grazing trials are necessary to determine the true worth of range management practices designed to preserve the huge range resource and increase its many economic, social and aesthetic values. Techniques must be tested on a wide range of plant communities and different environmental conditions before their application can be extensively recommended. Optimum seasons, intensities and systems of grazing are needed for native and seeded range and for areas where low-value trees and shrubs have been converted to grassland.

1. Native ranges. In answer to the question, "How should a ponderosa pine-bunchgrass range be grazed to maintain maximum production of forage and beef?" the findings of a long-term study in Colorado provide useful answers. Herbage production and plant cover increased under light grazing (10-20 percent utilization of the major forage species), remained about the same or increased slightly under moderate grazing (30-40 percent utilization), and decreased under heavy grazing (utilization 50 percent or more). Individual animals gained most under light grazing but the most

efficient and economical returns per acre were obtained from moderate grazing.

Effective livestock grazing systems periodically defer or delay grazing and usually result in improved forage conditions. This and other points to consider in selecting a grazing system to assure sustained production and utilization of the greatest quantity of high quality forage consistent with other land uses and values are published in USDA AIB-315.

Increasing land values in recent years have caused owners of commercial pine forests of south Georgia and north Florida to take a new look at the integration of timber and cattle production. Systems of utilizing forage in recently planted or naturally regenerating pine stands where burning must be deferred for several years have shown cows, using 20 acres of unburned forest per cow supplemented with limited improved pasture (0.6 acre), produced 85 percent calf crops with calves weighing 450 pounds. The results demonstrate that cows get a considerable portion of their feed from unburned young pine sites and early in the timber rotation such areas are of appreciable value to the rural landowner.

Despite a general abundance of grass in the South, beef breeding herds grazing throughout the year on pine forest ranges are often plagued by malnutrition. Feeding cottonseed cake during winter reduces mortality and increases calving percentages. Various modifications of the feeding program have effected a saving of 16 percent in feed cost. Cows receiving 312 pounds of supplement between November 1 and March 31 were as productive as those fed 432 pounds from October through May, or 555 pounds fed throughout the year. Moreover, periodic analyses of blood revealed no nutritional deficiencies in the cattle.

Herbage yield and cover, which concern the stockman-timber grower on longleaf pine-bluestem range in Louisiana, were greater on moderately or heavily grazed areas than on those ungrazed. Botanical composition remained relatively constant under moderate use but changed markedly on the other areas. Also, the moderate use treatment damaged pine regeneration less than the heavy. Grazing compacted the soils slightly but did not accelerate erosion. On cutover forest land utilized only as range, heavy grazing yields more beef than moderate grazing and can be recommended if confined to level or gently sloping sites with stable soils.

For the rancher in Arizona results from the Santa Rita Experimental Range show that proper utilization of the forage crop removes between 35 and 55 percent of the annual yield of perennial grasses. Annual and periodical adjustments in stocking are often needed to keep utilization within these limits. By maintaining a flexible herd, with breeding animals making up not more than 70 percent of the herd and normal selling of 8-year-old cows, downward adjustments can be made during dry years without reducing the productive breeding herd. In above-average years excess forage can be utilized by holding over weaner calves or by purchasing young animals.

Range management in the Ozarks region has often been ineffective and uneconomic because little information was available about areas of cattle use, forage dietary deficiencies and forage preferences. On the Mark Twain National Forest in southwest Missouri, cattle used old fields and open glades in late spring feeding mainly on forbs. Subsequently they fed on browse and mushrooms in woods in early summer, on grasses and sedges in mid- and late summer in old fields and open glades, and on fallen fruits and grass in brushy glades and open woods during fall months. Although forage deficiencies are alleviated by cattle selectivity, a phosphorus and protein s plement is recommended. The cattle owner can locate calf creep feeders and supplemental feeding stations in accordance with cattle pattern of use and promote increased weaning weights of calves and improved maintenance diets of cows.

Sagebrush-grass ranges can be improved by manipulation of vegetation with grazing rather than by costly spraying, burning, or mechanical treatments. At the U.S. Sheep Experiment Station near Dubois, Idaho, heavy late-fall grazing (60 sheep-days per acre) was as effective as complete protection in maintaining ranges in good condition. Grasses and forbs increased more than 30 percent, while sagebrush decreased 20 percent. However, spring grazing (40 sheep-days per acre) caused rapid deterioration of good-condition range; from 1951-1963 production of sagebrush increased 78 percent and production of grasses and forbs decreased more than 50 percent. Spring rest, combined with heavy grazing in the late fall, apparently offers a good method of range improvement.

Similarly, as shown in studies in Utah, two years' deferred spring grazing has given a substantial reduction of the poisonous weed halogeton (Halogeton glomeratus). Since its discovery in Nevada in 1934 it has spread over vast areas of the Intermountain region. Its abundance and persistence on crested wheatgrass range is influenced by four interrelated factors: (1) intensity of spring grazing, (2) season of grazing, (3) salts in the soil, and (4) total precipitation during July-September of the previous year plus May-June precipitation in the current year.

The best balance of seasonally preferred forage species and cattle weight gains were obtained through yearlong grazing of a California annual grass range. Natural clovers were twice as abundant on yearlong ranges as on units grazed during the winter or summer periods. The clovers are high in protein and remain green longer than most species. The system favored soft brome (Bromus mollis) and maintained a high percentage of ripgut brome (B. rigidus), both of which are early growing, preferred species. The latter species also increased with grazing either during the dry summer or the wet winter season. Because ripgut brome provides grazeable herbage 2-3 weeks earlier than most other species, the results suggest it may be profitable for a ranch to alternately graze special units during the winter or dry forage season to keep a high proportion of ripgut brome.

2. Improved ranges. Crested wheatgrass (Agropyron desertorum) can fill an important need for early spring grazing in the Intermountain region. Under conditions in central Utah (elevations 5,600-5,800 feet; rainfall 13 inches) crested wheatgrass may be grazed from about April 20 to June 20 at an intensity that removes approximately 65 percent of herbage by weight. Approximately 2.5 acres for one cow-calf unit, or 1.5 acres for one yearling animal is required for 2 months of spring grazing. This intensity of use will give optimum cattle gains per acre and maintain grass production. Delaying the start of grazing in the spring contributes to maximum basal area and yields of grass; shortening the grazing season at the end of the season contributes toward maximum plant numbers. Combinations of these principles mitigate adverse effects of heavy grazing.

There is also an urgent need for spring forage in northern New Mexico to benefit small livestock producers of the Spanish American farming communities. For sustained use of crested wheatgrass an average intensity of 65 to 70 percent utilization by weight of herbage during a month-long spring season was found to be optimum. Cattle made gains of 20 to 34 pounds per acre depending on the stocking rate and grazing intensity.

Stands of crested wheatgrass also made excellent lambing range in northern New Mexico. Benefits were 4 to 7 percent larger lamb crops and 1 to 3 percent smaller death losses than on native sagebrush ranges. When ewes lambed on crested wheatgrass the return to the operator was increased from 19 to 27 percent over returns from those lambed on native sagebrush range.

C. Burning and Other Range Improvement Practices

Hot June fires set for range improvement on the Santa Rita Experimental Range, Arizona, killed 90 percent of the burroweed (Haplopappus tenuisectus), half of the cactus (Opuntia spp.), and one-fourth of the mesquites (Prosopis juliflora var. velutina), that were less than one-half inch in basal diameter. Burroweed reinvaded rapidly in years of high winter moisture but few mesquite seedlings became established on the burned area. The direct effects of burning on perennial grasses lasted only one or two seasons but concentrated grazing of the burned area by jackrabbits and cattle prevented full recovery. Obviously range that is burned to control shrubs must be carefully managed to reestablish good stands of perennial grasses.

Switch cane (Arundinaria tecta) is one of the most productive native grazing types in the United States, but under continuous protection from fire, stands lose vigor and thin out. In North Carolina greatest foliage production occurred 3 to 4 years after burning in open cane and 2 to 3 years under pine canopy. There was a reduction of 31 percent in stem numbers between the 8th and 11th year of fire protection. Therefore, to keep cane stands most productive, fire should be introduced at intervals of about 10 years and coupled with carefully regulated grazing.

Parry rabbitbrush (Chrysothamnus parryi) is a vigorous competitor for soil moisture, nutrients and space with more desirable forage species. On Black Mesa in western Colorado successful kill was obtained with foliage sprays of Tordon 22K applied at 2 pounds per acre when new growth was between 3 to 6 inches long and the plants were in the early stages of flowering. A 100-percent kill of the undesirable Fremont geranium (Geranium fremontii) was also achieved. The spray treatment significantly increased grass production but there was a corresponding decrease in forbs, some of which are palatable to livestock. Total herbaceous production was approximately the same on the treated and untreated plots. Utilization by cattle was noticeably heavier on the small spray plots than on the surrounding range. In previous treatments cattle were reluctant to graze large sprayed areas where large bunchgrasses become overly rank and unpalatable after spraying. Possibly by reducing the size of the area this problem could be avoided.

Rootplowed and seeded chaparral lands on the Tonto Springs Experimental Range, Arizona, supported about three times as many animal units as native chaparral. Native chaparral, which occupies about 4 1/2 million acres in Arizona, produced 10.8 pounds of beef per acre compared to 40.0 pounds of beef per acre from chaparral sites that had been rootplowed and seeded. Rootplowing can be done for about one-third the cost of buying the same additional grazing capacity through land purchase. Based on beef at 25¢ per pound, gross returns would be $2.70 per acre from brushlands and $10.00 per acre from rootplowed lands.

On annual rangeland of California application every 3 years of 60 pounds of sulfur per acre has resulted in 50 percent increases in herbage and beef yields. Sulfur fertilization with helicopters is an economic practice on the rolling granitic soil topography. Cost of application and material averaged $4.11 per acre over a 3-year period.

D. Range Pest Influences and Control

Changes in herbage production which can be attributed to pocket gopher control on Black Mesa Experimental Forest and Range in western Colorado have been relatively small. Differences that exist are due to plant burial by gopher mounts or casts and to harvesting of plants by gophers. In addition, although their burrowing activities have been suspected of being detrimental to soil moisture, the moisture regime of mountain grassland soil has been little affected by exclusion of gophers for 10 years. From these studies it appears that gopher damage on these areas is so small that control measures are uneconomical.

In contrast a high population of pocket gophers in Utah practically destroyed a newly seeded grass stand in 6 years. Gophers were then closely controlled for 5 years, and marked increases occurred in grasses and forbs. During the next 3 years, gophers were not controlled; their population

increased rapidly and again seriously depleted the forage. On an adjacent seeded area, gophers were controlled for the entire period, and an excellent stand of seeded grasses and tall forbs was maintained continuously. There is need for an effective and economical method of controlling gophers on seeded areas although the benefits of control may be limited on some range areas.

Publications - USDA and Cooperative Program

RPA 110 - APPRAISAL OF FOREST AND RANGE RESOURCES

Range Resource Evaluation

Bjerregaard, Richard S. 1967. Weighing forage samples on windy ranges. J. Range Manage. 20: 331-332.

Holmgren, Arthur H., and Reveal, James L. 1966. Checklist of the vascular plants of the Intermountain Region. USDA Forest Serv. Res. Pap. INT-32. 160 pp.

Jameson, Donald A. 1967. The relationship of tree overstory and herbaceous understory vegetation. J. Range Manage. 20: 247-249.

Mason, Lamar R., and Hutchings, Selar S. 1967. Estimating forage yield on Utah juniper from measurements of crown diameter. J. Range Manage. 20: 161-166.

Matthews, Verl B. 1968. Tall bluebell, an important forage plant on aspen range in Utah. Utah Sci. 29: 17-19, 23.

Sanderson, H. Reed. 1967. Herbage production on high Sierra Nevada meadows. J. Range Manage. 20: 255-256

RPA 112 - RANGE MANAGEMENT

Characteristics and Requirements of Range Plants

Duvall, V.L., and Linnartz, N.E. 1967. Influences of grazing and fire on vegetation and soil of longleaf pine-bluestem range. J. Range Manage. 20: 241-247.

Frischknecht, Neil C. 1967. How far will halogeton spread? J. Soil & Water Conserv. 22: 135-139.

Green, Christine R., and Martin, S. Clark. 1967. An evaluation of precipitation, vegetation and related factors on the Santa Rita Experimental Range. Meteorol. & Climatol. of Arid Reg. Tech. Rep. 17. Tucson: Inst. Atmos. Phys. Univ. Ariz. 82 pp.

Grelen, H.E., and Epps, E.A., Jr. 1967. Herbage responses to fire and litter removal on southern bluestem range. J. Range Manage. 20: 403-404.

Laycock, William A. 1967. How heavy grazing and protection affect sagebrush-grass ranges. J. Range Manage. 20: 206-213.

Laycock, William A., and Conrad, Paul W. 1967. Effect of grazing on soil compaction as measured by bulk density on a high elevation cattle range. J. Range Manage. 30: 136-140.

Laycock, William A., and Conrad, Paul W. 1967. Effects of grazing and soil moisture on bulk density on the Diamond Mountain cattle allotment. Forest Serv., Intermountain Reg. Range Improv. Notes 12: 10-13.

McDonough, W.T., and Tew, R.K. 1967. Inhibitors of germination and growth from red elderberry: a laboratory evaluation. USDA Forest Serv. Note INT-72. 7 pp.

Mueggler, W.F. 1967. Response of mountain grassland vegetation to clipping in southwestern Montana. ECOL. 48: 942-949.

Pase, Charles E., and Thilenius, John F. 1968. Composition, production and site factors of some grasslands in the Black Hills of South Dakota. USDA Forest Serv. Res. Note RM-103. 8 pp.

Pearson, Henry A. 1967. Cattle diet digestibilities determined from components. J. Range Manage. 20: 405-406.

Pearson, Henry A. 1967. Effect of delays in inoculum collection on artificial rumen digestibilities. J. Range Manage. 20: 332-333.

Pearson, Henry A. 1967. Phenology of Arizona fescue and mountain muhly in the northern Arizona ponderosa pine type. USDA Forest Serv. Res. Note RM-89. 4 pp.

Pearson, Henry A. 1967. Range animal nutrition. 5th West Texas Ranch Manage. Conf. Proc. Oct. 13, Texas Tech. Coll., Lubbock, Texas, Spec. Rep. 3: 66-82.

Potter, Loren D., and Krenetsky, John C. 1967. Plant succession with released grazing on New Mexico rangelands. J. Range Manage. 20: 145-151.

Rice, R.W., and Johnson, W.M. 1967. Intake and digestion estimates of grazed forage. West. Sect. Amer. Soc. Anim. Sci. Proc. 18: 267-272.

Skovlin, Jon M. 1967. Fluctuations in forage quality on summer range in the Blue Mountains (of Oregon). USDA Forest Serv. Res. Pap. PNW-44, 20 pp.

Smith, D.R. 1967. Gross energy value of aboveground parts of alpine plants. J. Range Manage. 20: 179-180.

Smith, D.R., Fisser, H.G., Jefferies, N., and Stratton, P.O. 1967. Rotation grazing on Wyoming's Big Horn Mountains. Wyo. Agr. Exp. Sta. J. 13. 26 pp.

Springfield, H.W. 1967. Percentage of filled fourwing saltbush seeds. USDA Forest Serv. Res. Note RM-81. 4 pp.

Tiedemann, Arthur R., and Pond, Floyd W. 1967. Viability of grass seed after long periods of uncontrolled storage. J. Range Manage. 20: 261-262.

Van Dyne, G. M., and Vogel, W. G. 1967. Relation of Selaginella densa to site, grazing and climate. ECOL. 48: 438-444.

Livestock Grazing Practices

Bjugstad, A. J., and Dalrymple, A.V. 1968. Behavior of beef heifers on Ozark ranges. Missouri Agr. Exp. Sta. Bull. B870. 15 pp.

Driscoll, Richard S. 1967. Managing public rangelands: Effective livestock grazing practices and systems for National Forests and National Grasslands. USDA AIB-315. 30 pp.

Duvall, V.L., and Hansard, S.L. 1967. Responses of southern range cattle to protein supplementation. J. Range Manage. 20: 153-157.

Frischknecht, Neil C. 1968. Factors influencing halogeton invasion of crested wheatgrass range. J. Range Manage. 21: 8-12.

Laycock, W.A. 1967. How heavy grazing and protection affect sagebrush grass ranges. J. Range Manage. 20: 206-213.

Pearson, Henry A., and Jameson, Donald A. 1967. Relationship between timber and cattle production on ponderosa pine range--The Wild Bill range. USDA Forest Serv. Rocky Mountain Forest and Range Exp. Sta. 10 pp.

Smith, Dwight R. 1967. Effects of cattle grazing on a ponderosa pine-bunchgrass range in Colorado. USDA Tech. Bull. 1371. 60 pp.

Southwell, B.L., and Hughes, R. H. 1967. Beef cattle management practices for burned and unburned pine-wire-grass ranges of Georgia. Georgia Agr.Exp. Sta. Rep. 14. 18 pp.

Springfield, H.W., and Reid, Elbert H. 1967. Crested wheatgrass for spring grazing in northern New Mexico. J. Range Manage. 20: 406-408.

Burning and Other Range Improvement Practices

Bentley, Jay R. 1967. Conversion of chaparral areas to grassland: techniques used in California. USDA Agr. Handbook 328. 35 pp.

Cable, Dwight R. 1967. Fire effects on semidesert grasses and shrubs. J. Range Manage. 20: 170-176.

Crawford, H.S., and Bjugstad, A.J. 1967. Establishing grass range in the Southwest Missouri Ozarks. USDA Forest Serv.Res. Note NC-22. 4 pp.

Duncan, Don A. 1967. How range fertilization can increase forage and beef yields. Memorias de la Session Technica, Chihuahua, Mexico, X Anniversario Centro Nacional de Investigaciones Pecurias, SAG: 1-6.

Duvall, Vinson L., and Grelen, Harold E. 1967. Fertilization uneconomic for forage improvement in Louisiana pine plantations. USDA Forest Serv. Res. Note SO-51. 3 pp.

Hughes, R. H. Fire ecology of canebrakes. 1966. Fifth Annual Tall Timbers Fire Ecol. Conf. Proc. 149-158.

Laycock, William A., and Phillips, Thomas A. 1968. Long-term effects of 2,4-D on lanceleaf rabbitbrush and associated species. J. Range Manage. 21: 90-93.

Paulsen, Harold A., Jr., and Miller, John C. 1968. Control of Parry rabbitbrush on mountain grasslands of western Colorado. J. Range Manage. 21: 175-177.

Pond, Floyd W. 1967. Conversion of chaparral and scrub hardwood to productive range. Herbicides and vegetation management in forests, ranges, and non-croplands. Symp. Corvallis, Oregon, Sept. 7-9.

Springfield, H.W., and Bell, Donald G. 1967. Depth to seed fourwing saltbush. J. Range Manage. 20: 180-182.

Wright, Henry A. 1967. Contrasting responses of squirreltail and needle-and-thread to herbage removal. J. Range Manage. 20: 398-400.

Range Pest Influences and Control

Laycock, W. A., and Krebill, R. G. 1967. Comandra, grazing, and comandra blister rust. USDA Forest Serv. Res. Pap. INT-36. 9 pp.

Laycock, W. A., and Krebill, R. G. 1967. Comandra is not an invader on most western ranges. USDA Forest Serv. Intermountain Reg. Range Improv. Notes 12: 1-5.

WILDLIFE HABITAT MANAGEMENT

(RPA - 904 - WILDLIFE AND FISH BIOLOGY AND HABITAT

IN FORESTRY ENVIRONMENTS)

USDA and Cooperative Program

Location of Intramural Work	Scientist Man-years FY 1968
Arizona	3.0
California	1.6
Colorado	1.0
Idaho	0.7
Montana	2.1
Oregon	3.0
Pennsylvania	1.0
South Dakota	3.0
Texas	3.0
Utah	1.1
Virginia	2.0
West Virginia	3.0
Wisconsin	1.0
Wyoming	1.0
Total	26.5

Intramural program is supplemented by extramural support representing (a) 0.6 SMY's at State Agricultural Experiment Stations, (b) 0 SMY's at other U.S. institutions and (c) P.L. 480 funds in 1 country representing 26,348 U.S. dollars equivalent, (FY 1968).

Problems and Objectives

Providing an abundance of healthy wildlife on public and private lands is of National importance. In addition to the sportsman's pursuit of wildlife and its economic value, game and non-game species including songbirds are enjoyed as part of the natural landscape. However, poor logging practices, wildfire, road construction, strip mining or overuse by livestock or big game and other disturbances too frequently represent a travesty in conservation and challenge wildlife and fish habitat research. Knowledge of the requirements of food and cover of each species is essential to maintain these populations of wildlife. Species in danger of extinction must be afforded protection and their habitat must be improved to insure their preservation for future generations of people. Feasible means must be found to incorporate the needs of wildlife into the multiple use scheme.

Forest wildlife and fish management requires investigation in the following areas:

1. Selection, genetic improvement and methods of seeding or planting for both native and exotic food and cover plants.
2. Habitat rehabilitation as through type conversion and coordinated management to harmonize wildlife production with other uses.
3. Ecological and physiological requirements of wildlife habitats.
4. Improving fish habitat and food supplies.

Progress - USDA and Cooperative Programs

RPA 904 - WILDLIFE AND FISH BIOLOGY AND HABITAT IN FORESTRY ENVIRONMENTS

A. Wildlife Habitat Improvement

Improvement of wildlife habitat requires the development and evaluation of such special practices for increasing food and cover as seeding, planting, burning, spraying and fertilizing. Satisfactory methods of revegetation are particularly needed to restore seriously depleted big-game winter ranges of the West. Improvement measures are also needed for naturally unproductive habitats and for the establishment of desirable streamside vegetation. Wildlife habitat improvement generally results in beautification of the landscape. Also many of the plant materials and seeding and planting methods are useful in camping, picnicking and other recreational areas.

Eastern hemlock (*Tsuga canadensis*) is a valuable cover species for ruffed grouse (*Bonasa umbellus*) and other forest game, but it has been greatly reduced in many forested areas of the Northeast. In attempts to reestablish hemlock by artificial means, the survival of germinates was highest and

seedlings grew best when planted on a north aspect in understocked, orchard-type hardwood stands. Seedlings, however, must be protected from deer where browsing pressure is high. Fencing costs may be justified, however, if hemlock is the limiting factor and intensive management for grouse is a planned objective.

Openings within large acreages of closed forest ameliorate the forest habitat and increase animal and bird populations. A series of openings were chosen to represent the range feasible to maintain, and animal use, microclimate and insect populations were studied within and around these openings. Animals in northern hardwood forests appear to favor openings with diameters twice the surrounding tree heights (D:H = 2:1). Extremes of temperature and humidity are greater in these openings, while those less than 1/2 the tree heights differ little from the closed forest. Openings of intermediate size are warmer in daytime than either forest or open fields. No clearcut relation was evident between biting insects and white-tail deer use of openings.

Songbird populations in forest types of the Southeast showed significantly more breeding birds in uncut oak-poplar-white pine stands than in the mixed oak-pine stands of the Ridge and Valley Province. Bird abundance was otherwise similar. Within a cover type more birds were found in cut than uncut areas during the breeding and late summer seasons; populations on cut and uncut areas were similar in the fall. During the winter more birds were again found in cut stands. Cutting altered the habitat of certain species of forest birds; however, those species maintained populations in adjacent uncut stands. The habitat needs of songbirds and other non-game species which add to the aesthetics of the environment are becoming increasingly important to the multiresource manager.

California quail (Lophortyx californicus) is a highly prized game bird in the annual grass and woodland type whose habitat is altered for several years after the use of prescribed fire. However, the diet of quail on burned range differs very little from that on unburned range. Legume seeds were the most important food on both areas in the summer. Fire did not destroy the hard coated legume seed and quail returned to the area to use it immediately after the fire. The prominent legume species were Spanish clover (Lotus americana), bicolor lupine (Lupinus bicolor) and several clovers (Trifolium spp.). Once the fall rains began quail on both sites quickly switched from a seed to a leafage diet.

A comprehensive bibliography of 820 references summarizes the available literature on the use of burning as a resource management tool. Work published since 1938 concerning properties, uses and effects of controlled and uncontrolled fire is emphasized. The references are listed alphabetically by author and in addition are placed into 16 subject categories according to content to increase its utility.

Crownvetch (Coronilla varia) shows good adaptation to the mountain brush type in central Utah on 3-year-old test plots and appears promising for planting as game forage. Good stands have been established from direct seeding and transplanting of different strains. Since this legume is not native, the seed must be innoculated before planting with the nodule-forming bacteria (Rhizobia). The species' propensity for retaining considerable green foliage through the winter indicates its suitability for winter as well as summer forage.

Bitterbrush (Purshia tridentata) seed which is collected for planting on big-game ranges in the Western United States often reveals dark spots on the seed coat. Seed collectors and users should recognize this as lower quality seed. In germination tests, these spotted seeds were found to be damaged; the germinative capacity was 50 to 82 percent of unspotted seed.

Browse seeding programs in southwestern Idaho for game range improvement should aim for establishment of 800 to 1000 bitterbrush plants per acre. Sowing 12 to 16 seeds per spot at 1.25-inch depth is recommended. Scientists and managers working on restoration of depleted ranges will find a newly prepared annotated bibliography of bitterbrush a useful source of ready information.

Some selections of rubber rabbitbrush (Chrysothamnus nauseosus), from trial plantings on winter ranges in Utah, are fast-growing and highly palatable to game and livestock. A widely adapted and palatable strain of big sagebrush (Artemisia tridentata) also shows promise. Both shrubs have strong establishment attributes when aerially seeded in mixtures with grasses and forbs. Because of rapid development, they are ready to graze much more quickly than other shrubs and usually about the same time as the herbaceous species sown with them.

Treatment of stem cuttings with indolebutyric acid appears to be a practical way of rooting fourwing saltbush (Atriplex canescens) for satisfactory transplants. The technique will be particularly useful for providing seed of the most desirable specimens for range seedings. Once perfected the treatment can likely be applied to other shrubs.

B. Integration of Wildlife, Livestock, and Timber Production

Successful integration of wildlife and timber production in various forest types requires information on effects of timber stand structures, on forage and coniferous seed or hardwood mast production and on reciprocal effects of wildlife on timber production. To harmonize use by livestock and wildlife it is essential to know the nature and degree of competition for forage at different seasons of the year and how management practices can be modified to allow most efficient utilization of the entire resource.

Ways to grow game and timber,too, in the South are becoming a workable reality through research. Up-to-date findings which are briefly summarized in a well illustrated, factual release by the Southern Forest Experiment Station show that the first few years following timber cutting, one deer per 20 acres had little effect on the vegetation. As the tree canopy began to close and many browse plants grew out of reach, deer heavily browsed the more palatable species and those they had avoided earlier. Well-planned burns were then employed to keep palatable browse within reach of the deer and also improve the quality of the forest game food.

Pine-hardwood uplands in the South which have been planted to grow merchantable pine timber offer food and cover for deer and other wildlife with proper management. Browse yields in a loblolly pine (Pinus taeda) plantation were directly related to the amount of pine thinned at ages 20 and 25 years. At plantation age 35, five growing seasons after a third thinning, browse yields were inversely related to pine-thinning intensity. Many of the young hardwoods and shrubs had grown beyond the reach of white-tail deer (Odocoileus virginianus). Through the middle and late years of a plantation woody undergrowth was increased by selective felling of large hardwoods which released the suppressed plant growth within reach of deer.

Removal or knocking down of timber during logging road construction lowered the dissolved oxygen content to marginal levels for coho salmon and steel-head in a stream in northern California typical of small coastal streams which are important for anadromous fish spawning. Concentrations in treated sections of the stream were as low as 5 ppm versus 10 ppm on unaltered sections. Also, the pH level was lowered, turbidity increased and water temperatures increased in the stream following treatment. Through under-standing of the degree and duration of changes in stream characteristics following logging or other disturbances, rehabilitation measures and/or precautionary guides are being developed.

Open forest habitat in eastern Oregon best met the wildlife needs for food and cover in spring, summer, and fall. Its high value was due mainly to an abundance of elk sedge, a preferred grasslike plant. Grassland rated a close second in the spring when succulent flowering plants were abundant. However, it dropped to third during the summer and fall periods when the plants became dry and unpalatable. Low growing shrubs contributed most to the diet in the dense forest. The grassland rating rose slightly in the fall when a small amount of regrowth occurred on grasses.

Important possibilities for improving deer habitat in connection with multiple resource management in the Southwest include: (1) leaving aspen patches in mixed conifer forests and (2) making cattle stocking adjustments in ponderosa pine habitats. Aspen patches produce much more forage than adjacent conifer forests; associated deer use is about double. Deer use in ponderosa pine habitat is not influenced by slope; cattle prefer more

level areas. If grazing capacity for cattle is based upon proper use of the more gentle topography, ample forage for deer is automatically reserved on the steeper slopes.

The practice of converting chaparral to grass in Arizona should provide for leaving some untreated chaparral on northerly exposures where dual use by livestock and deer is an important consideration. Pellet-group counts indicate that mule deer (Odocoileus hemionus) prefer south-facing slopes cleared by rootplowing and seeded to exotic lovegrasses (Eragrostis spp.) They make most use of north-facing exposures left in natural brush.

C. Evaluation of Wildlife Habitat

The value of various habitats for the production of wildlife can be estimated in a number of ways. Quantities of herbage, mast, and berries and their chemical composition are important indicators of productivity, especially if food preferences and cover requirements for various species of wildlife are known. Likewise, actual observations on use of food and cover can provide information on habitat value. However, reliable methods for measuring and sampling forage production and utilization must be devised before adequate appraisals can be made.

Browse mixtures are essential, particularly on winter range, for continuous health and well-being of mule deer. Big sagebrush in north central Colorado is the No. 1 winter browse species in nutrient content and digestibility. However, it attains its potential only in mixed browse stands or where sagebrush adjoins other preferred browse stands. Sagebrush in the absence of other food is apparently unpalatable and may even be detrimental to deer.

The seasonal progression of crude protein, ash, and phosphorus content of plants on summer and winter deer ranges in this region generally declined from late spring to late fall and then increased slightly by late winter. Crude fat percentages generally rose from late spring to late summer, declined to late fall, and rose again to late winter. Calcium was variable with species but tended to decline from late spring to late fall and then increase to late winter. Crude fiber tended to increase from late spring to late winter in most of the species tested.

Nutritional analyses coupled with digestion trials of deer foods indicate that deer summer range in Colorado is nutritionally superior to winter range during the period of use. Because of the abundance and superior quality of summer range forage, females are enabled to meet the contingencies of late-term fetus nourishment and subsequent lactation; animals also attain the excellent condition so essential for wintering. Thus efforts should be made to retain summer range in good condition and a variety of browse species, both deciduous and evergreen, for a better balanced diet on winter range.

Certain forbs in the Wasatch Mountains, Utah, are important as forage and withstand reasonable grazing by both big game and livestock. Clipping the plants annually for ten years showed ligusticum (Ligusticum porteri), valerian (Valeriana edulis), and geranium (Geranium richardsoni) suffer little damage with approximately 50 percent utilization. More severe clipping decreased herbage and flower stalk production; at 90 percent plants were drastically reduced in size and after 3 or 4 years no seed was produced. Mortality did not occur until the seventh year of this severe treatment which allows management time to take corrective measures to avoid overuse before there is permanent damage to the habitat.

At age 5 years, twig growth of food species for wildlife in southern pine-hardwood forests averaged nearly seven times more for plants grown in open than for those beneath trees. Since twig growth is closely related to browse yields the difference is equal to a substantial increase in deer forage. Fruit yields for seven species was 32 times higher for plants in the open than in the woods. American beauty-berry (Callicarpa americana) was the highest yielder of browse forage and fruit.

The relative carrying capacity for deer of the major forest types of the Atlantic Upper-Coastal Plain near Aiken, South Carolina, ranged from 12-13 acres per deer in loblolly-scrub hardwood and bottom land hardwood stands to 104 acres per deer in young pine plantations. Weight of desirable browse ranged from 6 pounds per acre in young pine plantations, the least productive site, to over 130 pounds per acre in bottom land hardwoods, the most productive browse site. Ratings were obtained from an inventory of the abundance of preferred or "candy" species; staple species which constitute the bulk of the deer diet, emergency species and "stuffing" species or those having little or no food value.

Two mammal repellents, ZAC (zinc dimethyldithiocarbamate cyclohexylamine complex) and TMTD (tetramethylthiuram disulfide) effectively protected chokecherry (Prunus virginiana), American plum (P. americana), aspen (Populus tremuloides), and caragana (Caragana arborescens) from deer browsing in the Black Hills of South Dakota. Protection was tested by measuring current annual twigs removed during the period of winter use by white-tailed deer and mule deer. These repellents provide an alternative to expensive and laborious fencing and caging of experimental plants and plots, and also may prove to be useful in browse revegetation projects.

Another promising possibility for reducing deer damage to young conifer plantations is through the use of deer attractants. Some examples of attractants are 1) application of molasses or other sweeteners, minerals or trace elements which increase a plant's palatability to deer; 2) planting of choice food plants in the potential damage area; 3) providing supplements such as hay, pellets or trees and large brush plants which are felled so that deer can feed on foliage that they otherwise could not reach.

Deer prefer forage grown on the Tyson series (oak) and the Melbourne series (Douglas fir) forest soils in the North Coast region of California. Deer densities based on pellet group counts indicate that the forest soils support a higher deer population (287 deer per square mile) than the Yorkville, Kneeland, and McMahon series of grassland soils. McMahon soil supported the fewest deer (45 deer per square mile). Yorkville soils which sustained the highest deer use of grassland soils provide a greater variety and higher production of forbs than do the other two grassland soils. Melbourne soils rank second in deer use as deer utilize the Douglas-fir stands on these soils for escape cover and protection from weather.

There were 19 staple and preferred food items eaten by prairie grouse in 13 South Dakota counties. Rose (Rosa spp.) and western snowberry (Symphoricarpos occidentalis) were present in the diet in all four seasons. Cultivated crops (barley, oats, wheat, corn sorghum), as a group, were most important in winter (56 percent by volume). Insects were the most important food item (24 percent) for sharptails (Pedioecetes phasianellus) in summer. Food of prairie chickens (Tympanuchus cupido pinnatus) consisted of rose in summer, fall, and winter. Important seasonal foods were insects, corn, and poison ivy (Toxicodendron radicans), respectively.

Winter range available for mule deer in the sagebrush type in central Colorado is limited principally by snow depths exceeding 1 1/2 feet (or less if crusted). Up to 90 percent of the sagebrush range cannot be used in severe winters in which case there is extensive animal mortality. With near-average snow approximately half the range is unavailable by early winter and half of the remainder becomes so by mid-winter. The problem in severe winters may require provision of high forage densities on limited sites.

Small openings created by timber harvesting practices in lodgepole and spruce-fir timber improve mule deer summer habitat in the central Rocky Mountains. Deer use of alternating strips of cut and uncut timber, 1 to 6 chains wide, was 2 to 3 times greater than use of nearby uncut mature forest. Heaviest use was in the cut strips. On clearcut areas of 50 to several hundred acres, use was usually less than in the adjacent forest.

In the Southwest immature age groups of ponderosa pine (less than 11.5 inches dbh.) were preferred for bedding by mule deer rather than areas of trees of older age groups. Immature tree groups above 160 square feet basal area per acre, were preferred, exceeding other density situations by 2 to 10 times. This suggests that not all immature stands should be thinned heavily for timber stand improvement where deer production is an important multiple use.

Pellet group counts which are widely used as a management tool to estimate big-game numbers and follow trends in range use may be simplified by using frequency to estimate density (number of groups per plot). In the

Pacific Northwest, frequency determinations (number of plots on which one or more pellet groups occur expressed as a percentage of the total plots examined) are quite rapid and subject to little personal bias. Frequency counts may be particularly useful on uniform areas with dense ground cover where pellet group dispersion is random. However, frequency counts may be less efficient than complete counts and may also be biased if the pattern of dispersion is non-random.

An electronic instrument which rapidly and accurately estimates herbage yield has been very useful for measuring production on small shrubs at the Desert Experimental Range, Utah. On dense perennial bunchgrass range the instrument gave high accuracy when compared to clipped samples; however, early in the year when the grass is short or sparse accuracy is severely reduced. Stands of cheatgrass (Bromus tectorum) dry unevenly and the variance in moisture content between plots reduces accuracy. Sampling with the meter is difficult on seeded stands which have been drilled.

Publications - USDA and Cooperative Program

RPA - 904 - WILDLIFE AND FISH BIOLOGY AND HABITAT IN FORESTRY ENVIRONMENTS

Wildlife Habitat Improvement

Basile, Joseph V. 1967. An annotated bibliography of bitterbrush (Purshia tridentata (Pursh) DC.) USDA Forest Serv. Res. Pap. INT-44, 27 pp.

Cushwa, C.T. 1968. Fire: A summary of literature in the United States from the mid-1920's to 1966. Bibliogr. USDA Forest Serv. Southeastern Forest Exp. Sta. Pap. 117 pp.

Czuhai, E., and Cushwa, C.T. 1968. A resume of prescribed burning experiences on the Piedmont National Wildlife Refuge. USDA Forest Serv. Res. Note SE-86. 4 pp.

Duncan, Don A. 1967. Food of California quail on burned and unburned central California foothill rangeland. Calif. Fish and Game 54: 123-127.

Ferguson, Robert B. 1967. Relative germination of spotted and nonspotted bitterbrush seed. J. Range Manage. 20: 330-331.

Ferguson, Robert B., and Basile, Joseph V. 1967. Effect of seedling numbers on bitterbrush survival. J. Range Manage. 20: 380-382.

Jordan, James S., and Sharp, Ward M. 1967. Seeding and planting hemlock for ruffed grouse cover. USDA Forest Serv. Res. Pap. NE-83. 17 pp.

Plummer, A. Perry. 1966. Experience in improving salt-desert shrub range by artificial planting. In: Salt-Desert Shrub Symp. Proc. USDI Bureau of Land Manage. 130-146.

Plummer, A. Perry. 1967. Experimental crownvetch plantings. USDA Forest Serv. Intermountain Reg. Range Improv. Notes 12: 13-14.

Plummer, A. Perry, Christensen, Donald R., and Monson, Stephen B. 1967. Highlights, results, and accomplishments of game range restoration studies. 1966. W-82-B-11. Utah State Dept.Fish and Game Pub. No. 67-4-(W-82-B-11). 45 pp.

Segelquist, C.A., and Halls, L. K. 1967. History and status of forest game habitat research in the South. Southeast. Assoc. Game and Fish Commissioners 20th Annu. Conf. Proc. 1966: 1-5.

Stearns, Forest. 1967. Wildlife habitat in urban and suburban environments. N. Amer. Wildlife and Natur. Resources 32d Conf. Trans. 61-69.

Integration of Wildlife, Livestock, and Timber Production

Blair, R. M. 1967. Deer forage in a loblolly pine plantation. J. Wildlife Manage. 31: 432-437.

Gysel, Leslie, and Stearns, Forest. 1968. Deer browse production of oak stands in central Lower Michigan. USDA Forest Serv. Res. Note NC-48. 4 pp.

Halls, L. K., and Oefinger, S.W., Jr. 1968. Research to grow game with our timber. USDA Forest Serv. Southeast. Forest Exp.Sta. 25 pp.

Harlow, R.F., and Palmer, Z. F. 1967. Clearcutting in coordinated deer-timber management in the Southern Appalachians. Wildlife In N. C 31: 14-15.

Stransky, J.J., and Halls, L.K. 1967. Timber and game relations in pine-hardwood forests of the Southern United States. In: Int. Union Forest. Res. Organ. 14th Congr. Proc. 7: 208-217.

Thilenius, John F., and Hungerford, K.E. 1967. Browse use by cattle and deer in northern Idaho. J. Wildlife Manage. 31: 141-145.

Evaluation of Wildlife Habitat

Dasmun, Raymond F., Hubbard, Richard L., Longhurst, William M., et al. 1967. Deer attractants--an approach to the deer damage problem. J. Forestry 65: 564-566.

Dietz, Donald R., and Tigner, James R. 1968. Evaluation of two mammal repellents applied to browse species in the Black Hills. J. Wildlife Manage. 32: 109-114.

Dzieciolowski, Ryszard. 1967. Food of the red deer in an annual cycle. Acta Theriologica 12, 37: 503-520.

Dzieciolowski, Ryszard. 1967. Winter food of the red deer (Cervus elaphus L.) as determined by tracking techniques. Ekologia Polska-Seria A. 14(11): 285-305.

Evans, Keith E., and Kerbs, Roger R. 1967. Waterfowl and shorebird use on selected stock ponds in Jackson County: 1966 S.Dak. Bird Notes 19: 28-30.

Halls, L.K., and Alcaniz, R. 1968. Browse plants yield best in forest openings. J. Wildlife Manage. 32: 185-186.

Julander, Odell. 1968. Effect of clipping on herbage and flower stalk production of three summer range forbs. J. Range Manage. 21: 74-79.

Kerbs, Roger R. 1967. Wild turkey attempts nesting near Rapid City, S. Dak. Bird Notes 19: 61.

Larson, Joseph S. 1967. Forests, wildlife and habitat management--a critical examination of practice and need. USDA Forest Serv. Res. Pap. SE-30. 28 pp.

Lyon, L. Jack. 1968. An evaluation of density sampling methods in a shrub community. J. Range Manage. 21: 16-20.

Lyon, L. Jack. 1968. Estimating twig production of serviceberry from crown volumes. J. Wildlife Manage. 32: 115-119.

Moore, W. H. 1967. Deer browse resources of the Atomic Energy Commission's Savannah River Project. USDA Forest Serv. Resource Bull. SE-6. 28 pp.

Moore, W. H., and Johnson, F. M. 1967. Nature of deer browsing on hardwood seedlings and sprouts. J. Wildlife Manage. 31: 351-353.

Reynolds, H. G. 1967. Chemical constituents and deer use of some crown sprouts in Arizona chaparral. J. Forest. 65: 905-908.

Pearson, Henry A. 1967. Rumen microorganisms in buffalo from southern Utah. Appl. Microbiol. 15: 1450-1451.

Ripley, T.H., and Halls, L.K. 1966. Measuring the forest wildlife resource. In: Measuring the Southern Forest. pp. 163-184. La. State Univ. 15th Annu. Forest. Symp. Proc. 1966. La. State Univ. Press.

Shafer, Elwood L., and Liscinsky, Stephen A. 1968. Design and analysis for multiple use studies of deer browse and timber production. USDA Forest Serv. Res. Pap. NE-100. 25 pp.

Short, H.L. 1967. Forage analyses for deer management studies. Southeast. Assoc. Game and Fish Commissioners 20th Annu.Conf. Proc. 1966: 15-18.

FOREST PROTECTION RESEARCH

FOREST FIRE

USDA and Cooperative Program

Location of Intramural Work	Scientist Man-Years F.Y. 1968			
	Research Problem Area			Total
	109	113	203	
Alaska			2.0	2.0
Arizona			2.0	2.0
California			31.0	31.0
Colorado			3.0	3.0
Georgia			13.0	13.0
Minnesota			2.0	2.0
Mississippi			2.0	2.0
Missouri			2.0	2.0
Montana	3.0	4.0	13.0	20.0
Washington			4.0	4.0
Total	3.0	4.0	74.0	81.0

Intramural program is supplemented by extramural support representing (a) 0.0 SMY's at State Agricultural Experiment Stations, (b) 0.0 SMY's at other U.S. institutions, and (c) P.L. 480 funds in 1 country representing 28,982 U.S. dollars equivalent.

Problems and Objectives

Forest fires have a continuing impact on every major wild land resource in all parts of the Nation. Forest fires are becoming more costly. Public and private expenditures for fire control now exceed 250 million dollars per year. Forest fire losses also continue to increase. The average loss per fire increased 250 percent between 1962 and 1966 despite a strenuous and costly effort to promptly rehabilitate burned-over areas in order to reduce damage. Population pressures are changing the nature and increasing the complexity of forest fire problems. Suburbs merge gradually into the wild lands so that fires today involve homes as well as trees, and the safety of people becomes a major complicating factor in tactical firefighting decisions. The opportunities for forest fire research to make significant reductions in both forest fire costs and damages are greater than ever before. Recent advances in many scientific fields can be developed through the forest fire research program for specific application to forest fire problems.

Major objectives of forest fire research are to:

1. Develop methods of preventing fires with emphasis on situations causing the greatest costs and losses.
2. Develop effective and economical methods for reducing the hazards of dangerous forest, brush and range fuels.
3. Develop new and more effective techniques for detecting and suppressing fires burning under a variety of fuel, weather and topographic situations.
4. Develop fire control systems for improved protection from fire in intermingled forest and urban areas.
5. Develop improved ability to predict fire potential and fire behavior with emphasis on early warning of incipient conflagration conditions.

Progress - USDA and Cooperative Program

RPA 109 - WEATHER EFFECTS, PROBABILITIES AND AGRICULTURE DECISION MAKING

Scientists at the Northern Forest Fire Laboratory have demonstrated that complete glaciation of cumulus clouds can be achieved at certain temperatures with their newly developed cloud seeding equipment and technology. This is a big step in lightning research, as complete glaciation is an essential step in lightning modification.

These scientists discovered two other important factors about cloud seeding. One is that silver iodide crystals can be introduced through a warm cloud base and still act as effective ice-forming nuclei. This is in contradiction to recent theories which indicate that silver iodide would lose much of its effectiveness if introduced from below cloud base. The other is that the observed ice crystal concentrations in seeded clouds appear to be two

or three orders of magnitude greater than the calculated silver iodide nuclei concentration. This suggests that a mechanism of ice crystal formation other than that due directly to artificial ice nuclei must be active in seeded cumulus clouds.

RPA 113 - REMOTE SENSING

A. Aerial Photography

Research Foresters at Seattle, Washington, are developing methods to determine the kind, height, and density of understory vegetation from aerial photographs. They have photographed two dense mature tanoak-pacific madrone stands in southwestern Oregon at scales of 1:4000, 1:8000 and 1:12,000 with Ektachrome Aero Type 8442 and Aero-Neg Type 2448 films. These photographs were tested against twenty-two combinations of scale, exposure, flight-line orientation and rendition to determine their suitability for interpreting height and density of understory brush. Brush height measurements were accurate within the limits of instrumental error and brush density measurements were in agreement with ground measurements 70 percent of the time. These techniques will prove useful for broad-scale mapping of fuel types as a basis for fire control planning.

B. Airborne Infrared

Forest Service scientists have demonstrated that airborne infrared line scanners produce useful thermal images of latent lightning fires in total darkness, and through smoke, smog and haze. Detecting these fires at night would permit suppression while poor burning conditions prevail keeping fires small.

Detection probability experiments were conducted with small charcoal fires in forests of the white pine-cedar-hemlock type in northern Idaho and in the Douglas-fir type on the western slopes of the Cascade Mountains. Measurements indicate that latent fires can be detected with 80 percent probability in most western timber types at vertical angles of 0° to 50° from the nadir. Detection probability drops off rapidly beyond 50°, approaching zero at 70°. Also, signal strength from the fires became very weak at angles above 40°, particularly in the Douglas-fir type. This suggests that fire patrol in these heavier timber types will have to be modified to maintain good signal strength.

The Northern Forest Fire Laboratory detected 600 fires from 21 patrol flights over National Forests in the Northwest. Fifty-nine of these were identified as wildfires; the others were campfires, debris fires, etc. Determining what type of fire has been detected requires a knowledge of ground conditions and geography of the area. A target discriminator developed at this laboratory permits accurate locations of fires from the infrared imagery provided the plane is precisely navigated and the imagery is rapidly processed.

RPA 203 - PREVENTION AND CONTROL OF FOREST FIRES

A. Fire Physics and Chemistry

1. Spot fires and vortices in a wild land fire. Spot fires were formed 8 to 10 miles ahead of the main fire front on the 20-mile long Sundance Fire of Idaho. This was the largest of 46 large fires that burned out of control in the northwestern United States during the late summer of 1967. Evidence collected by scientists studying the Sundance Fire indicates that vortices in the air may be responsible for starting these spot fires. These vortices are formed downwind of the convection column, and may be responsible for carrying firebrands long distances beyond the fire front. Subsequent vortices moving over the area can fan the fires started by these firebrands, causing them to spread rapidly. Other evidence collected by this study indicates that vortices in the form of fire whirls in the main fire front may even be the mechanism for breaking fuel loose and raising it into the air to become a firebrand. This new knowledge of how firebrands are created and transported will help develop techniques for combating similar fires.

2. Heat transfer is measured under three fire spread conditions. Scientists at the Northern Forest Fire Laboratory have measured the surface temperature of a pine needle while conducting fire spread experiments in a wind tunnel with a pine needle fuel bed. These experiments were conducted under three contrasting spread conditions: (1) a fire spreading with the wind, (2) a fire backing into the wind, and (3) a fire spreading in the absence of wind. Analysis of these measurements has shown that by contrasting the needle's temperature with the proximate air temperature the types of heat flux and the portions of the preheating curve at which each type is dominant in bringing the fuel to ignition can be identified. The heading fire heats the fuel rapidly and the fuel surface is always cooler than the proximate air showing that the heat transfer process is primarily convective during the preheating phase. In contrast; the backing fire heats the fuel slowly and the heat transfer process is primarily radiant during the preheating phase. The no-wind case is similar to the backing case with radiant heat dominating. In all three cases convective heat transfer dominates when the fire envelopes the particle. These findings on heat transfer will increase our ability to predict fire behavior.

3. Two new facts about the heat needed to ignite forest fuels. The heat of preignition (the heat necessary to raise a fuel to ignition) of fine forest fuels has never been experimentally verified. This is a fundamental property that must be known before meaningful mathematical models of fire spread can be developed. Measurements from initial experiments have produced two advances over earlier work. (1) Fine forest fuels have a temperature gradient from the surface to the center contrary to previous assumptions. Consequently, the surface will reach ignition temperature before the center and predictions of the heat of preignition based on uniform heating and related to the total weight of the particle will be too high. (2) There are

endothermic as well as exothermic reactions associated with the pyrolysis of volatiles and neglecting these will lead to low predictions of the heat of preignition.

4. A review of thermal radiation measurements and a new technique. Scientists in California have undertaken a review of thermal radiation measurements obtained from a score of experimental fires over a 4-year period. The objective was to separate the useful data from the questionable or extraneous, to assemble this material for source use, and to correlate the information with respect to its possible contribution to the quantitative prediction of large fire behavior. The useful material has been assembled and annotated. The data are limited to measurements performed at modest elevations outside the fire periphery. On no fire were sufficient measurements obtained to permit inference of an energy balance--an objective that becomes more difficult as fire size increases.

Thermal radiation measurements are needed in order to characterize large-scale fires. Because of the highly variable nature of such fires, a large number of these measurements are needed, both outside and inside the fire perimeter. Researchers have found one way to obtain these measurements by fabricating a dosimeter from two standard aluminum-end beer cans. These meters, first used in a 30-acre experimental fire, are simple, inexpensive, easily fabricated, lightweight, self-contained, rugged and capable of withstanding a hot fire environment.

5. The effect of heating crystalline cellulose. One study has shown that the crystallinity of cellulose, as well as its purity, markedly affects its pyrolysis behavior. Further, noncrystalline cellulose rapidly develops a crystalline pattern on heating. However, the X-ray diffraction pattern of heated crystalline cellulose is relatively unaffected until well over half the sample has pyrolyzed.

6. Potassium has a significant effect on fire. Potassium concentrations greater than 15,000 parts per million (p.p.m.) practically eliminate flaming combustion in cellulosic material such as forest vegetation. At lower concentration variations of as little as 1,500 p.p.m. cause significant changes in flaming combustion. Scientists in Arizona are studying the variations in potassium concentration that occur in both turbinella oak and pointleaf manzanita. They have measured natural increases of potassium of 2,900 p.p.m. in a range of 4,000 to 6,900 p.p.m. in manzanita and 1,300 p.p.m. in a range of 7,400 to 8,700 p.p.m. in oak between July and October. Theoretically these changes could have reduced flaming combustion significantly in manzanita and noticeably in oak. Also, the lower range in manzanita compared with oak suggests more flaming when manzanita burns, and observations bear this out.

Spraying with phytocides such as 2,4-D and 2,4,5-T has reduced the potassium concentratinn by up to 3,200 p.p.m. in manzanita and 2,800 p.p.m. in oak over a 2 to 3 week period. This should increase flaming significantly in

both species. Understanding the effect and being able to modify the concentrations of potassium in forest vegetation will give us the capability to more effectively use fire to modify vegetation.

7. Transglycosylation during pyrolysis of cellulose. A research project in Israel under Public Law 480 is studying the possibility that transglycosylation occurs during the pyrolysis of cellulose. They examined the charred residues obtained after cellulose had undergone pyrolysis for 5-hours at 250° under continuous evacuation. The same treatment was applied to a sample of filter paper, with the methozyl content of the sample and the filter paper being determined before and after hydrolysis.

B. Atmospheric Physics and Forest Fire Meteorology.

1. The sea breeze has many features important to fire. The Southern Forest Fire Laboratory has recorded over 100 sea breeze frontal passages on a three-station surface weather observation network in coastal Georgia during a 1-year period. Analysis of these recordings has shown the following features that are important to fire behavior: (1) frontal passages are frequent enough in all seasons to be a potential hazard to coastal fires, (2) they occur at the time of day that fire danger is greatest, (3) they carry with them an abrupt shifting of wind direction and an increase in wind speed, (4) winds converging into the frontal zone provide inflow into any fire, and the resulting vertical wind velocities increase the intensity, convection and spotting of a fire, and (5) frontal passages are slow, and thus will influence a fire for a long time. Knowledge of these features can add to the safety and effectiveness of the fireman.

This surface weather data has also shown that certain conditions are necessary for passage of a sea breeze front at any location in coastal Georgia. These are: (1) the location must be close enough to the sea to be reached by the front, (2) the temperature over the land at the location must be greater than that of the sea surface, and (3) the precedent flow must be from land to sea, and less than a certain threshold value. These findings can be used in forecasting passages of the sea breeze front.

2. Convergence causes high incidence of lightning fires. Scientists in Georgia have discovered one of the factors causing the high incidence of lightning strike fires in the vicinity of the Okefenokee Swamp. They analyzed the average fields of horizontal velocity divergence of surface winds for a 5-year period. This analysis showed that there is a late afternoon convergence maximum in the vicinity of the swamp. Convergence is one property that contributes to thunderstorm activity, and they concluded that this high incidence of lightning-strike fires is due, at least in part, to the fact that the convergence has a diurnal maximum in the vicinity of the swamp.

3. High-quality fire danger rating observations are not always the best. A research study in Mississippi analyzed 3-months' fire danger data to compare one high-quality observation from the center of an area to a number

of poorer quality observations within the area. Their results gave an r^2 value of 0.52 for the correlation between the numbers of fires and the average danger ratings of the several stations and an r^2 value of 0.37 for the same correlation with a single central station. Likewise, when comparing fire size, r^2 was 0.44 for the average station data and 0.30 for the central station data. Thus, a number of poorer quality observations within an area are more representative of the fire danger than are high-quality observations from the center. This will provide the land manager additional information for determining the optimum number of fire danger rating stations for his area.

4. Knowledge of part precipitation needed to calibrate rain gages. To obtain the optimum calibration of the tipping bucket rain gage requires knowledge of the precipitation climatology in the area where it is used. Scientists have reviewed earlier precipitation studies in southeastern Georgia in order to calibrate rain gages that will be used in a later study. Their review showed that approximately 50 percent of the yearly rainfall occurs during the months of May, June, July and August. Most of this is showery in type, and is associated with thunderstorm activity. Individual locations may experience precipitation rates of from 9 to 12 inches per hour for short time intervals of less than 5 minutes. The other 50 percent of the annual average precipitation is associated with hurricanes, fronts and wintertime air masses. The short-duration rates of showery precipitation that may occur during this period are not as great as those for the months of May through August.

5. Twenty-five years of precipitation records of the Intermountain West are analyzed. A study at the Northern Forest Fire Laboratory has analyzed 25 years of precipitation records in the Intermountain West. This analysis revealed the existence of distinct time patterns of precipitation probability. Recognizing these patterns will make it possible to prepare better long range seasonal plans for resource management. By altering requirements so as to tolerate more or less precipitation, the planner can readily determine how many available days can normally be expected for such requirements.

6. The Loop Fire disaster investigated. Scientists in California have completed a detailed investigation of the fire weather of the Loop Fire Disaster that took the lives of 12 experienced firefighters on the Angeles Forest, November 1, 1966. They found that there was no general, unpredicted change in wind directions. The weather and fire behavior were typical of the fuel, topography and Santa Ana weather conditions under which the fire burned. The results of this investigation are being used to prevent such accidents in the future.

C. Fuels and Fire Behavior

1. Tables and techniques developed for estimating tonnage and hazard of slash. About 50,000 acres of young ponderosa pine are thinned each year on the National Forests of Oregon and Washington. The unwanted trees, mainly

of 6-inch d.b.h. and smaller, are left as they fall. A project in Washington has developed tables and techniques for estimating both tonnage of slash and probable hazard rating of these thinnings. These show that rate of fire spread is usually high for at least 5 years, and in some instances resistance to control also remains high that long. This information provides a partial basis for determining the need for special fire protection measures to protect the investment in thinning.

2. A method is developed to estimate the amount of new and old surface fuel. Scientists have developed a method to estimate the amount of new and old surface fuel in shortleaf pine stands of southeast Missouri. Forest cutting operations increase the amount and exposure of surface fire fuels in the remaining stand which increases the fuel hazard and potential fire damage. These cutting operations also increase the dead surface fuel by reducing the green crown fuels. The new method for estimating the amount of surface fuel is based on the relations of the weights of crown foliage, branchwood and forest floor fuels to tree stand basal area. A simple computation shows amounts of ground fuel and fuel added by partial cuttings.

3. Flame size affects fire spread. Experiments at the Northern Forest Fire Laboratory, Missoula, Montana, have shown that fires in different fuel types have flames of varying height, and that the size of a flame front significantly affects the rate of fire spread in laboratory tests. Determination of the configuration factor for a given flame shape provides a method for relating flame fronts of various widths. The configuration factor of an irregularly shaped flame can be determined with the aid of an analog system. The relation between any width bed and an infinitely wide bed can be determined from the integrated configuration factor. The analog system also indicates the change in radiant heat flux to the fuel as the flame is tilted by wind or slope changes. These findings provide knowledge of how fire spreads through forest fuel.

4. The color of cheatgrass indicates its moisture content. One other study at the laboratory has determined the relationship of color changes associated with the curing of cheatgrass to plant moisture content (M.C.). There are three stages of color change. The three stages and associated moisture contents are: green - more than 100 percent, purple - 30 to 100 percent, and straw - less than 30 percent. The drop in moisture content occurs quickly, taking about 2 weeks. The start of the drop depends on prior climatic conditions, and will not occur at the same calendar date on different sites.

5. Several techniques used to measure physical properties of forest fuel. The Fuel Science Project in Missoula employed several techniques for measuring and describing particle size, particle density, fuel loading and fuel porosity of wild land ground fuels. They found three methods to be suitable for measuring particle size and density. These are: integration of cross-sectional area and perimeter with length for uniform shapes, blueprint

outline and thickness measurement of flat shapes, and electrolytic conductivity and water displacement of silver castings for irregular shapes. They tested these methods on two fuel types, ponderosa pine litter and cheatgrass. They found the surface area-to-volume and specific gravity average to be 57.6 $cm.^2/cm.^3$ and 0.51 for ponderosa pine needles and 144.0 $cm.^2/cm.^3$ and 0.34 for cheatgrass.

They used a modified line intercept sampling technique to measure fuel bed properties. This technique provides accurate estimates if it is assumed that the line may intersect a fuel particle at any angle. Assuming that the line intersects these particles at only right angles may give as much as 30 percent error. Using this technique for both fuel beds they made accurate estimates of fuel bed porosity from particle spacing with a correlation coefficient of 0.83 for each. Analysis of the physical properties of the fuel is a prerequisite to understanding how fuel affects fire behavior.

In addition to these physical properties of fuel, the project conducted tests of the ignition temperatures of individual pine needles. Results of the tests showed that the heat flux required for spontaneous ignition of the needle section is 2.72 $B.T.U./ft.^2$-sec. at a furnace temperature of 802^oF.

6. Mineral content influences the ignition and burning of forest vegetation. Fuel scientists are analyzing 25 species of fuel to determine the influence of mineral content on the pyrolysis process. These species had mineral contents ranging from 0.1 to 27 percent by dry weight. Analysis of two of these species, medusahead and cheatgrass, showed that at least one of the minerals does not influence pyrolysis. Medusahead with 18 percent total minerals and cheatgrass with 4 percent have a similar pyrolytic rate. However, medusahead's silica content is 17 percent and cheatgrass's is 3 percent, leaving only 1 percent of other minerals in both species. Also, if the silica is removed, all 25 species offuel have a log-log relationship to their maximum weight loss in nitrogen from thermogravimetric analysis. This indicates that some minerals in addition to silica are not reactive. In addition, thermogravimetric and differential thermal analysis show that pyrolysis starts at lower temperatures and leaves higher organic residues as silica-free ash increases.

7. Pyrolysis of wood and its components. A study under contract with the University of Montana has shown that the pyrolysis characteristics of wood is equal to the sum of the pyrolysis characteristics of its components. Hemicellulose starts to pyrolyze at a lower temperature than the other wood components. The findings are important since it brings us one step closer to being able to predict the ignitability and fire behavior characteristics of any forest fuel once we know its chemical composition.

8. Environmental chamber used to study moisture in fuels. Laboratory scientists have investigated a group of diverse fine fuels to determine their equilibrium moisture content under various weather conditions expressed in

terms of timelag constants. They subjected fuel particle samples to step changes in relative humidity from 20 to 90 percent in an environmental chamber. This produced time lag constants that varied from 5 minutes for cheatgrass to 235 minutes for ponderosa pine needles.

Preliminary experiments with solar insolation indicate fuels are quite sensitive to radiant heating. Fuels exposed to 1 cal./cm.^{2}-min. of solar heat at 90 percent relative humidity lost enough moisture in 2 hours to be the same as if the relative humidity had dropped to 20 percent.

9. Fire researchers can predict the rate of fire spread. A paper on predicting rate of fire spread using heat transfer and fuel descriptors is the most recent output of one study. Fire researchers can predict the rate of fire spread in mat-type fuels by using the equations for radiant and convective heat transfer. They estimate that the maximum heat flux required to maintain the experimental rates of spread at low moisture contents is 3 cal./cm.^{2}-sec. with about 40 percent being contributed by radiant heat. This study found that the residence time of a flame front in a fuel bed was related to the fuel particle diameter or thickness and that the residence time in minutes was equal to eight times the particle thickness in inches. They achieved correlation between liquid pool fires and mat-type litter fires by considering the ratio of fuel density and convection column gas density. Results from this study will pave the way for predicting the rate of fire spread in other fuels.

10. Rate of fuel consumption increases when fuel moisture drops. A study at the Southern Forest Fire Laborotory with burning beds of natural fuel particles has shown that as the moisture content decreases, the rate of weight loss increases. A drop in fuel moisture from 30 to 12 percent will increase the rate of fuel consumption by one-third, and a drop from 12 to 4 percent will increase the rate by one-half. This relationship between moisture content and rate of weight loss is similar for both slash pine and loblolly pine needle fires. However, the relationship is quite different for hardwood leaves which burn with lower rates of weight loss than pine needles at the same moisture content. Also, mechanical compaction of the fuel bed has very little effect on the burning rate of pine needles, whereas it has a significant effect on the burning rate of hardwood leaves. Understanding these fuel moisture relationships is another prerequisite to understanding fire behavior.

11. Many simple correlations found for moisture in Arizona chaparral. Scientists in Arizona have found that there are simple correlations between foliar moisture of chaparral and days since rain, air temperature, a drought index, a fire-danger index, relative humidity, partial vapor pressure, wind velocity and net radiation. They have calculated simple correlation coefficients as high as 0.782 for turbinella oak on net radiation in a dormant season and 0.781 for pointleaf manzanita on drought index in a growing season. Also, they have produced simplified equations that have enabled them to calculate multiple correlation coefficients up to 0.876 for individual dormant

and growing seasons. The drought index was the variable with the highest significance in seven out of eight analysis periods, and it correlated best with the manzanita foliage moisture.

12. New handbook available on conversion of chaparral areas to grasslands. An Agriculture handbook on conversion of chaparral areas to grasslands is a recent output from fire research in California. It is the result of 15 years of research and study. Some significant findings described in this handbook are: chaparral areas can be economically converted to grass where the soil water storage is greater than 2 inches and the gradient is 40 percent or less; chamise chaparral and associated sage types are readily converted, but mixed chaparral dominated by scrub oak or other resistant species are not easily or cheaply converted; and there are many combinations of methods to remove brush, sow grass and kill brush regrowth with costs dependent on the combinations required.

13. Brush control in conifer plantations. A research project in northern California has discovered that the number of phenoxy herbicide spray applications proved more important to the control of brush in pine plantations than the kind or rate of any individual application. Three applications provided excellent control of total shrub regrowth. Without herbicide application, pines were being overtopped by brush by the fifth year. The most effective combination of brush control and cost is a herbicide mixture containing 25 percent 2,4,5-T and 75 percent 2,4-D at 4 pounds, acid equivalent, per acre. Most brush species are in the best physiological condition for good spray results during September and October, although regrowth of deciduous species should be sprayed in late August or early September. With these techniques, a forester can expect greater success with his pine plantations.

14. Laboratory develops method of establishing low growing plants. Researchers at the Forest Fire Laboratory, Riverside, California have developed methods of plant reproduction such that they can now establish nearly all of 10 saltbush species or strains from direct seedings. All saltbushes tested rooted satisfactorily from stem cuttings in a mist chanber. Saltbush seed may germinate if subjected to prolonged rain after maturity, and should be harvested soon after maturity. Saltbush is a low growing plant ideally suited for fuel breaks.

D. Fire Prevention and Use of Fire

1. Few differences found between problem and nonproblem debris burners. The Fire Prevention research staff in California designed a survey to compare problem debris burners in western Oregon (those who let their debris fires escape) with neighbors who had no recorded fire accidents. Data from the survey showed few differences between the two groups. Rural nonfarm residents are less likely to have a debris fire problem than rural farm residents. Problem burners feel that the fire problem in Oregon is not as serious as stated by the fire agencies. Also, 10 percent of the control group admitted

previous problems with fire. This lack of difference between the problem and nonproblem groups indicates that sooner or later anyone in either group might have a debris fire escape. Fire protection agencies can use this information to determine the direction of their fire prevention efforts.

2. Personal contact still necessary in fire prevention. The continuing study of fire hazard inspection procedures in Butte County, California, showed a substantial reduction in the number of violations the second year--from 63 to 49 percent. The reduction was most marked in incinerator standards and possession of required burning permits. The study found that personal contact was still necessary to get compliance in spite of previous year's exposure to the program.

3. Communication of forest fire prevention messages depend on several factors. Social scientists conducting forest fire prevention research in the Southern United States have determined several factors related to communication of forest fire prevention messages. Residents of a community with a high rate of fire occurrence, as compared to those of a community with a low rate, do more open range livestock grazing, and have lower levels of education and an unfavorable opinion of foresters. Residents retain mass media communicated fire prevention messages in keeping with their attitude toward forestry work. While the presence of forestry personnel in the area is known, acquaintance with them is minimal and quite casual. Fire prevention messages had been seen or heard by approximately two-thirds of the community within the past six months. Residents received fire prevention messages most frequently by television, signs and posters, but these media reached only half of the residents.

4. Spring burns for Upper Piedmont and summer burns for Lower Piedmont. The Prescribed Fire project at the Southern Forest Fire Laboratory has found that spring burns are significantly better than summer burns for top killing small hardwoods in the shortleaf pine-hardwood stands of South Carolina's Upper Piedmont. In addition, direct seeding of loblolly pine resulted in a first-year stocking of 53 percent on the burned plots compared with only 18 percent on the unburned.

However, summer prescribed fires were more successful in killing back understory hardwoods and aiding the establishment of free-growing loblolly pine seedings in Georgia's Lower Piedmont. Backfires and strip head fires were equally effective, but the strip head fires were less costly and influenced less by wind fluctuations in hilly terrain. New regeneration following summer fires was twice as plentiful as on unburned tracts.

5. Fifteen out of 60 slash plots burned. Scientists at the Northern Forest Fire Laboratory have burned 15 out of 60 fully instrumented 10-acre plots in spite of curtailment due to the critical fire season of 1967. They obtained weight loss data from water-can fire analogs that agreed with measurements of duff reduction. Also, they have produced an efficient, practical

sampling program (called 3P inventory) for slash fuels by modifying widely used Stand Examination Procedures to include all organic matter. Sufficient data was collected to permit the development of a computer program that will compare Stand Examination preharvest cruise data with 3P inventories of slash volume. These experiments will help determine the best time and techniques for burning logging residue.

6. Frequency of acceptable burning days in Minnesota determined. A study in St. Paul analyzed 10 years of Weather Bureau hourly surface observations to determine the frequency of suitable burning weather. This analysis disclosed that 25 to 40 acceptable burning days can be expected to occur in Minnesota each year. These days are most frequent during the months of July, August and October.

E. Fire Control Methods and Systems

1. High-expansion foam not feasible for open wood fires. The Fire Science Project in Seattle, Washington conducted a cooperative research study with the Seattle City Fire Department and the University of Washington to determine the feasibility of high-expansion foam for control of an unconfined, freely spreading fire. Preliminary results indicate that high-expansion foam (1) cannot be confined sufficiently to suppress high intensity fire in heavy wood fuel; (2) will not readily penetrate a moderately dense to dense wood fuel bed; and (3) cannot be depended upon to act as a fire barrier in heavy wood fuel. These results will save land managers any effort they might use in attempting to use foam on open fires.

2. Spread index and buildup index differ among stations in Alaska. A research project in Fairbanks has shown from an analysis of the southeast Alaska fire danger rating data that spread index and buildup index differ among fire weather stations. This agrees with a similar study in interior Alaska which suggested that fire control planning should be developed on the basis of areas having relatively uniform fire danger characteristics. This year's analysis also provides information on frequency, location, variation and severity of fire danger at these stations.

3. Fire danger rating and fire occurrence. The staff in Fairbanks also analyzed the fire reports for the years 1956 through 1965 to provide additional information useful for fire control planning. Their analysis showed that 44 percent of all fires occurred and 83 percent of the total acreage was burned when the buildup index was 60 or above. Also, 33 percent of all fires occurred and 34 percent of the total acreage was burned when the spread index was 40 or higher. Continued analysis will broaden the application to other areas, and enable fire control agencies to accelerate fire control activities as fire danger increases.

4. Fire danger rating and the 1967 fire season. Preliminary analysis of the disastrous 1967 fire season in the northwest by the Northern Forest Fire Laboratory indicates that the National Fire Danger Rating System Buildup

Index satisfactorily measured the severe burning conditions that developed. The National Fire Danger Rating System Spread Index also effectively identified the days on which large runs were made on going fires. The laboratory developed ADP card punching instructions for a proposed standard card format for the 10-day Fire Danger and Fire Weather Record. This will accelerate the analysis of fire danger rating data, and increase its usefulness to wildland managers

5. Lower viscosity retardants prove better for reducing fire spread. The Fire Management Project in Missoula conducted wind tunnel rate of fire spread experiments using phosphate and sulfate retardants of the same concentration and same total amount of salt, but different viscosities. Results showed that those with lower viscosity did a better job of reducing rate of spread. This agrees with previous observations, and suggests that for a given amount of salt a complete coat over all of the fuel is more effective than a thick layer on part of the fuel. The loss of ammonia during chemical analysis, and probably after field applications, appears to have little influence on the effectiveness of the remaining salt. This information will help fire control personnel decide the proper viscosities for each fire situation.

6. Fire crews lose effectiveness after eight hours. A study at the Forest Fire Laboratory, Riverside, California, collected data on handline construction rates on wildfires and correlated this data on ADP equipment with fuel, weather, topography and burning conditions. This study found that the effectiveness of crews is seriously impaired by fatigue after eight hours of work on a fire. Crews spend only an average of 33 minutes out of each hour actually constructing handline after they have passed the eight hour mark. In addition to this, their average rate of handline construction is reduced even when they are actually working. These two factors severely limit the usefulness of a crew on a wildfire for periods over eight hours.

7. A remote ignition system for backfiring. Research at the Southern Forest Fire Laboratory has developed a remote ignition system that utilizes a standard 12-gauge shotgun shell charged with $1\frac{1}{4}$ inch section of fusee material. Launched from any standard 12-gauge shotgun, this projectile has a range of from 100 to 400 feet, and has a burnout time of approximately 25 seconds. The purpose of a remote ignition system is to set fires behind a chemical retardant fire line and burn out strips ahead of a wildfire. A study was also conducted of the patterns of fire spread that develop from these point sources of ignition. Results showed that spot fires spaced one chain apart developed rapidly enough to complete the burnout of a control line ahead of a fire three chains deep in about 12 to 14 minutes under average fire weather conditions. This new technique will lead to more effective control of wildland fires.

Publications - USDA and Cooperative Program

RPA-109 - WEATHER EFFECTS, PROBABILITIES AND AGRICULTURAL DECISION MAKING

Fuquay, Donald M. 1967. Weather modification and forest fires. IN: Ground Level Climatology. Amer. Assoc. for the Advance. of Sci. Proc., pp. 309-325, illus.

Fuquay, D. M., R. G. Baughman, A. R. Taylor, and R. G. Hawe. 1967. Characteristics of seven lightning discharges that caused forest fires. J. Geophys. Res. 72(24): 6371-6373, illus.

Fuquay, D. M., R. G. Baughman, A. R. Taylor, and R. G. Hawe. 1967. Documentation of lightning discharges and resultant forest fires. U.S. Forest Service Res. Note INT-68, 7 pp., illus.

MacCready, P. B., Jr., and R. G. Baughman. 1968. The glaciation of an AgI seeded cumulus cloud. J. Applied Meteorolog. 7(1): 132-135, illus.

RPA-113 - REMOTE SENSING

Aerial Photography

Lund, H. G., G. R. Fahnestock, and J. F. Wear. 1967. Aerial photo interpretation of understories in two Oregon oak stands. U.S. Forest Service Res. Note PNW-58, 6 pp., illus.

Airborne Infrared

Hirsch, Stanley N. 1968. Infrared fire surveillance. McGraw-Hill Yearbook of Sci. and Technol., 177-178, illus.

Losensky, B. John. 1968. A preliminary report on the infrared lightning fire patrol study. Fire Control Notes 29(2): 4-6, 16, illus.

RPA-203 - PREVENTION AND CONTROL OF FOREST FIRES

Fire Physics and Chemistry

Anderson, Hal E. 1968. Fire Spread and Flame Shape. Fire Technology 4(1): 51-58, illus.

Broido, A. 1966. Thermogravimetric and differential thermal analysis of potassium bicarbonate contaminated cellulose. Pyrodynamics 4(3): 243-251, illus.

Kilzer, F. J., and S. B. Martin. 1967. A simple microcell for photometric monitoring of flowing materials. J. Chromatography 31(1): 204-208, illus.

McCarter, R. J., and A. Broido. 1967. Radiant energy dosimeter for field use. Fire Technology 3(3): 213-224, illus.

McCarter, R. J., and A. Broido. 1966. A calorimeter for determining radiation and convection in small-scale combustions. Pyrodynamics 4(2): 191-203, illus.

Rothermel, Richard C. 1967. Airflow characteristics--wind tunnels and combustion facilities, Northern Forest Fire Laboratory. Intermountain Forest and Range Expt. Sta., 32 pp., illus.

Atmospheric Physics and Forest Fire Meteorology

Brackebusch, Arthur P. 1967. Improving resource management planning with precipitation probability estimates. Master thesis on file at Univ. of Montana School of Forestry. 120 pp., illus.

Fosberg, Michael A. 1967. Numerical analysis of convective motions over a mountain ridge. Journal of Applied Meteorology, 6(5): 890-904.

Hauck, Charles A., and Dee F. Taylor. 1968. Project THEO basic surface network. (Abstract.) Bulletin American Meteorol. Soc. 49(1): 59.

Helvey, Roger A. 1967. Airflow in the San Bernardino-Riverside region "Santa Ana" of December 10-12, 1963. Dept. of Meteorology. University of California, Los Angeles. 27 pp., illus.

Lamb, Robert C., and James A. Pharo. 1967. Standardizing meteorological instrument testing. Bulletin American Meteorol. Soc. 48(9): 707-708.

Paul, James T., Dee F. Taylor, and Marshall P. Waters III. 1968. Some meteorological conditions associated with lightning-caused forest fires in southeastern Georgia. (Abstract.) Bulletin American Meteorol. Soc. 49(1): 56.

Ryan, Paul W., and Anthony M. Pachence. 1967. An analysis of 1966 forest fires and fire danger in Georgia. Georgia Forest Res. Council Res. Paper 47, 21 pp., illus.

Schroeder, M. J., M. A. Fosberg, C. A. O'Dell, and O. P. Cramer. 1967. Marine air invasion of the Pacific Coast: a problem analysis. Bulletin AMS. 48(11): 802-808, illus.

Shenton, L. R. 1967. Moments and maximum likelihood. Letter to the Editor. American Statistician 21(4): 52-53.

Taylor, Dee F., and Dansy T. Williams. 1967. Meteorological conditions of the Hellgate fire. U.S. Forest Service Res. Paper SE-29, 12 pp.

Taylor, Dee F., and Dansy T. Williams. 1967. Severe storm features of wildfires. (Abstract.) Bulletin American Meteorol. Soc. 48(8): 596.

Williams, Dansy T. 1967. A kinematic method for computing vertical velocity from horizontal winds aloft data at a single station. (Abstract.) Bulletin American Meteorol. Soc. 48(7): 503.

Williams, Dansy T. 1967. A local kinematic method for computing vertical velocity from horizontal winds aloft data at a single station. Proceedings, Fifth Conference on Severe Local Storms, American Meteorol. Soc., St. Louis, Mo. pp. 376-382.

Williams, Dansy T., and Charles A. Hauck. 1968. Fire behavior and the sea breeze front. (Abstract.) Bulletin American Meteorol. Soc. 49(1): 56.

Woodley, William L. 1967. An examination of an instance of heavy, non-frontal wintertime convective rain in the southeastern United States. Proceedings, Fifth Conference on Severe Local Storms, American Meteorol. Soc. St. Louis, Mo. pp. 198-208.

Fuels and Fire Behavior

Blackmarr, W. H., and William B. Flanner. 1968. Seasonal and diurnal variation in moisture content of six species of pocosin shrubs. U.S. Forest Service Res. Paper SE-33, 11 pp., illus.

Countryman, C. M. 1967. Thermal characteristics of pinyon pine and juniper fuels used in experimental fires. DASA Information and Analysis Center Special Report 59, Santa Barbara, California, pp. 309-319.

Countryman, C. M. 1967. Weight loss platforms to measure burning rate. DASA Information and Analysis Center Special Report 59, Santa Barbara, California, pp. 269-284.

Crosby, John S., and Robert M. Loomis. 1967. How thinning affects fuel weights in shortleaf pine stands in sourteast Missouri. J. Forest. 65(12): 901-902.

Fosberg, Michael A. 1967. Evaluation of the natural length scale in mass fires. DASA Information and Analysis Center Special Report 59, Santa Barbara, California, pp. 353-359.

Gaines, Edward M. 1967. Background and general progress of Project Flambeau. DASA Information and Analysis Center Special Report 59, Santa Barbara, California, pp. 240-242.

Gaines, Edward M. 1967. Project Flambeau experimental fire of June 14, 1966. DASA Information and Analysis Center Special Report 59, Santa Barbara, California, pp. 243-246.

Murray, John R. 1967. Instrumentation used in the June 14, 1966 experimental fire. DASA Information and Analysis Center Special Report 59, Santa Barbara, California, pp. 247-255.

Mutch, Robert W. 1967. Cheatgrass coloration--a key to flammability. J. Range Mange. 20(4): 259-260.

Pirsko, Arthur R., and Lisle R. Green. 1967. Record low fuel moisture follows drought in southern California. J. of Forestry 65(9): 642-643, illus.

Fire Prevention and Use of Fire

Altobellis, A. T., and Walter A. Hough. 1968. Controlling palmetto with fire and herbicides. Georgia Forest Res. Council Res. Paper 52, 4 pp., illus.

Baird, A. W., and Kaufman, H. F. 1967. An experiment in the prevention of man-caused fires. Forest Farmer 25(4): 9, 20-23, illus.

Brender, Ernst V., and Robert W. Cooper. 1968. Prescribed burning in Georgia's Piedmont loblolly pine stands. Jour. Forestry 66(1): 31-36.

Cooper, R. W. 1967. Training through presbribed fire seminars. Proceedings, Annual Tall Timbers Fire Ecology Conference, pp. 128-133.

Cooper, R. W., and Archer D. Smith. 1968. Simulating prescribed fires--a new training technique. Fire Control Notes 29(1): 11-13, 16.

Czuhai, Eugene, and Charles T. Cushwa. 1968. A resume of prescribed burnings on the Piedmont National Wildlife Refung. U.S. Forest Service Res. Note SE-86, 4 pp.

Folkman, William S. 1967. Evaluation of fire hazard inspection procedures in Butte, County, California. U.S. Forest Serv. Res. Note PSW-145, 13 pp., illus.

Geobel, N. B., E. V. Brender, and R. W. Cooper. 1967. Prescribed burning of pine-hardwood stands in the Upper Piedmont of South Carolina. Clemson Univ. Forest Res. Series 16, 22 pp., illus.

Griessman, B. E., and A. L. Bertrand. 1967. Factors related to cummunication of forest fire prevention messages. La. Agr. Expt. Sta. Bulletin 623, 31 pp.

Fire Control Methods and Systems

Barney, Richard J. 1967. Buildup indexes for interior Alaska 1956-1965. Pacific NW Forest and Range Expt. Sta., Inst. Northern Forest., Misc. Pub., 49 pp., illus.

Barney, Richard J., and William C. Fischer. 1967. Pocket calculator for local fire-danger ratings. Intermountain Forest and Range Expt. Sta., 8 pp., illus.

Bentley, Jay R. 1967. Conversion of chaparral areas to grasslands: techniques used in California. USDA Agric. Handbook 328. 35 pp., illus.

Cooper, R. W. 1968. Developments in forest fire research and their application to forest fire control. Forest Farmer 27(9): 8-10.

Cushwa, Charles T. 1968. Fire: a summary of literature in the United States from the mid-1920's to 1966. U.S. Forest Service, Southeast Forest Expt. Sta., 117 pp.

Dell, John D., and Franklin R. Ward. 1967. Incendiary projectile launcher tested for remote slash ignition. Fire Control Notes 28(4): 10, 15, illus.

Dell, John, and Franklin R. Ward. 1967. Remote ignition of logging slash--napalm grenades successfully tested. U.S. Forest Serv. Res. Note PSW-154, 4 pp., illus.

Dibble, D. L., and J. B. Davis. 1967. Fighting fire with high-pressure air jets--some preliminary results. Fire Control Notes 28(1): 12-13, 15, illus.

Dieterich, J. H. 1967. New technique speeds fire line construction. South. Lumberman 215(2680): 177-178.

Dieterich, J. H. 1967. Wildfire detection in the United States. A review of current practices and a look into the future. Proceedings, XIV IUFRO Congress, Vol. 5: 702-703.

Fahnestock, G. R. 1968. Forestry and the social sciences: a forester's view. J. Forest. 66: 22-25.

George, Charles W., and Charles E. Hardy. 1967. Fire retardant viscosity measured by modified Marsh Funnel. Fire Control Notes 28(4): 13-14, illus.

Green, L. R., and J. R. Bentley. 1967. Fuel-breaks for forest fire control. Span (London) 10(2): 96-101, illus.

Hardy, Charles E., and Charles W. George. 1967. Chemicals for forest fire fighting. Nat. Fire Protection Assoc., 2d ed., chapters 2, 3, 4, and 10.

Johansen, R. W., and J. W. Shimmel. 1967. Thickening retardants improves adhesion to tree crowns. U.S. Forest Service Res. Note SE-84, 3 pp.

Johnson, Von J. 1968. Buildup index as an expression of moisture content in duff. U.S. Forest Service Res. Note NC-43, 4 pp., illus.

Noste, Nonan V. 1967. Rate of perimeter increase related to timber spread index and northeastern fuel types. U.S. Forest Service Res. Note NC-40, 2 pp.

Orr, William J., and John D. Dell. 1967. Sprinkler system protects fire-line perimeter in slash burning. Fire Control Notes 28(4): 11-12, illus.

Plumb, T. R. 1967. Brushkiller to control scrub oak sprouts--combinations of broadcast and individual plant applications tested. U.S. Forest Serv. Res. Note PSW-146. 6 pp. illus.

Sackett, S. S., and J. H. DeCoste. 1967. A new mobile fire laboratory. Fire Control Notes 28(4): 7-9.

Schimke, Harry E., and Ronald H. Dougherty. 1967. Coating green slash--asphalt and wax prevent drying. U.S. Forest Serv. Res. Note PSW-143. 2 pp.

Schimke, Harry E., and Ronald H. Dougherty. 1967. Disposing of slash, brush, and debris with a machine loaded burner. Fire Control Notes 28(3): 7-9, illus.

Settergren, Carl D. 1967. The effects of fire on wildland hydrology. Ph. D. dissertation on file at Colorado State Univ. 218 pp.

White, Verdie E., and Lisle R. Green. 1967. Fuel-breaks in southern California, 1958-1965. Pacific SW Forest & Range Expt. Sta., U.S. Forest Serv. 33 pp., illus.

FOREST INSECTS

USDA and Cooperative Program

Location of Intramural Work	Scientist Man-Years F.Y. 1968			
	Research Problem Area			
	201	801	113	Total
Alaska	4.0			4.0
California	11.2		1.4	12.6
Colorado	4.0			4.0
Connecticut	9.0			9.0
Florida	4.0			4.0
Georgia	4.0			4.0
Idaho	3.5			3.5
Louisiana	6.0			6.0
Montana	1.5			1.5
Michigan	4.0			4.0
Mississippi	3.0	6.0		9.0
New Mexico	3.0			3.0
North Carolina	6.4			6.4
Ohio	11.0			11.0
Oregon	13.0			13.0
Utah	2.0			2.0
Total	89.6	6.0	1.4	97.0

Intramural program is supplemented by extramural support representing (a) 0 SMY's at State Agricultural Experiment Stations, (b) 0 SMY's at other U.S. institutions, and (c) P.L. 480 funds in 5 countries representing 180,910 U.S. dollars equivalent.

Problems and Objectives

Increasing demands on the Nation's forest resources -- including wood products, wildlife, water, and recreation -- necessitate greater protection against insects and other destructive pests. Insects adversely affect tree growth and value from the time it is a seed until it is harvested, and the use and value of the derived products similarly may be reduced. Better means are needed to minimize the continuous losses inflicted by insects and to prevent outbreaks. Changes in patterns of land use, forest management practices, and economic and aesthetic values, and concurrent technological developments in chemical and biological control methods are contemporary factors that complicate the planning and conduct of studies in forest insect research.

Major objectives of the research are:

1. To provide a better knowledge of specific pests and their interrelations with the forest environment.
2. To develop improved methods of detecting and evaluating forest insect infestations.
3. To develop more efficient methods of controlling pest insects and/or the damage caused by them.

Progress - USDA and Cooperative Program

RPA 201 - FOREST INSECTS RESEARCH

A. Biology and Ecology

1. Bark beetles. The extremely hot, dry summers of 1966-67 in western Montana were marked by the killing of many large groups of young, pole-size ponderosa pine trees by the pine engraver, Ips pini. These were most prevalent in the vicinity of recent pine thinnings and harvest cuttings. Intensive feeding by large numbers of beetles, coupled with the hot, dry conditions, led to rapid bark deterioration and a reduction in brood survival. After feeding for 2 to 3 weeks, the attacking adults abandoned the infested trees. These observations help explain the oft-observed sudden collapse of I. pini infestations in standing pine trees.

Closely related species of Dendroctonus bark beetles constitute a hazard if accidentally introduced into each other's natural hosts. If they are capable of interbreeding freely but produce sterile hybrids, this information is applied to biological control. Preliminary interbreeding experiments with D. simplex from eastern larch in Alberta, Canada, and D. pseudotsugae from Douglas-fir showed that western larch was the most suitable mutual host for interspecific pairings. However, female Douglas-fir beetles failed to produce progeny when paired with D. simplex males.

Stand characteristics have an important effect on mountain pine beetle activity in Utah. Sampling in two lodgepole pine stands revealed that larger-diameter trees having thicker bark were selected first by the beetles. This finding will aid in planning cuttings to reduce infestations and subsequent losses in mixed-age stands containing larger size trees.

Investigations of the seasonal development of the southern pine beetle in east Texas have shown that the insect may pass through as many as 7 consecutive generations during a single season. A summer generation was completed in as little as 26 days while 3-½ months were required for a winter generation. Winters are not cold enough to kill southern pine beetles in southeast Texas, minimum temperatures rarely falling below 10°F. During each of the past 3 winters, brood development advanced slowly during warm periods and then accelerated rapidly when air temperatures exceeded 50°F. in February. This means that in areas where infestations are known to occur, or where there has been a recent history of losses, scouting and control efforts should be continued throughout the winter.

Research continued on the effects of controlled drought and flooding on loblolly pine growing on low, poorly-drained coastal sites. This has shown that daily patterns of oleoresin exudation pressure (OEP) are related to both soil moisture level and vapor pressure deficit. OEP and relative water content are affected most during periods of extreme moisture stress, periods in which pine bark beetles are often very active.

Two species of fungi have been isolated from the mycangium or fungal tube of the female southern pine beetle. One is similar to the food fungus utilized by ambrosia beetles while the other is related to the blue stain fungi of the genus Ceratocystis. Similar microorganisms have been found in the western pine beetle. Studies of the effects of these microorganisms on the nutritional components of the inner bark have revealed marked changes in the sugar makeup of this tissue following infection. These changes may be vital to the growth and survival of young larvae, and modifying them might be a useful insect control approach.

Another important bark beetle, Dendroctonus adjunctus, has killed large numbers of pole-size ponderosa pines from southern Utah and Colorado southward to Guatemala in recent years. In southern New Mexico it was found that the insect has a 1-year life cycle, and attack activity occurs from mid-August to mid-October. The insect overwinters in the adult and egg stages; development resumes in March and is completed by late summer. This information makes it possible now to properly schedule control activities.

Intensive study of the biology of two species of oak bark beetles, Pseudopityophthorus minutissimus and P. pruinosus, suspected as being vectors of oak wilt, reveals that there are two and a partial third generations each year in southern Ohio. Most of the attacking adults of both species successfully attack 2 to 4 host trees. The insects overwinter in all stages except the pupal stage. The rapid development of these insects and their

capacity for attacking many hosts gives considerable emphasis to the need for early control action.

2. Defoliators. The feeding habit of the spruce budworm in western larch is not always consistent with that in other western Montana conifers. In young larch, the larvae do not confine their feeding to the foliage but sever stems of terminal and lateral shoots as well. This produces trees with multiple leaders and crooked boles. This altered feeding habit jeopardizes rapid early juvenile height growth and tree form - two highly desirable characteristics of western larch.

In the Lake States the spruce budworm is primarily a pest of mature spruce-fir stands. However, heavy infestations have recently occurred in sapling stands over large areas in northeastern Minnesota. The insects dispersed first into scattered overstory spruce trees left from previous logging. Later, young larvae spread to young spruce and balsam fir. Once on the balsam fir saplings, the larvae hollowed out the vegetative buds during their early spring feeding. These buds subsequently served as overwintering sites where none had existed before. Based on these findings, the removal of residual larger trees is recommended to reduce the chances of infestation of the younger trees in such stands.

Reductions in radial increment of grand fir, Douglas-fir, and Engelmann spruce subjected to defoliation by the spruce budworm in eastern Oregon are related to classifiable damage symptoms. The growth reduction generally differed significantly among four damage classes based on the amount of dead branches and twigs and the extent of top killing seen in the crowns. Radial increment also varied along the tree boles, being greatest at mid-crown and least near the ground. Top killing occurred often among moderately damaged trees, particularly in grand fir. This study suggests that crown vigor symptoms can be grouped into classes suitable for use in damage surveys.

After hatching in late summer, and also during emergence from hibernation in the spring, many small larvae of the jack-pine budworm fall to the ground and die. In the spring, losses may be 10 times greater than during the summer dispersal period. Greatest losses take place in the more open stands (30 square feet of basal area per acre or less). This finding may permit regulation of populations by reducing the density of host trees through selective thinning.

Several factors determined the numerical abundance of the gypsy moth over a 7-year period in New York State. In the case of older female larvae (instars IV - VI) in dense populations, disease was the primary cause of mortality. Agents other than disease or parasites were more important in sparse populations. The survival of female pupae in dense populations varied primarily in response to parasites and disease. Mortality of younger larvae (instars I to III) was influenced most by the dispersion rate of the newly-hatched larvae.

This information provides a sounder basis for the selection and application of control measures and a means for evaluating the long-range effectiveness of these measures.

Comparisons of outplanted ponderosa pines from Oregon with the highly susceptible native red pine in Michigan showed that relative infestation levels of European pine shoot moth during a five-year period were about the same for both species. This indicates that the shoot moth problem in the Pacific Northwest could be similar to that experienced in the North Central and Northeastern States.

A series of Scotch pine provenance test plantings became infested with European pine sawfly in the Lake States, offering an opportunity to evaluate genetic differences in resistance among 21 varieties from 108 Eurasian seedlots. Trees of the variety uralensis from the Ural Mountains were significantly less severely attacked for their height, while those of variety iberica were severely attacked. In all others, the severity of attacks was related to height. Tree breeders might now look for and utilize resistant varieties, such as uralensis.

Life history studies of the hemlock sawfly in southeast Alaska show that the insect overwinters primarily in the egg stage. The larvae pass through 4 or 5 feeding instars depending on sex. On the average, females each produce 72 eggs, and oviposition generally occurs in the upper portions of the tree crowns.

Mortality of western larch caused by the larch casebearer appeared for the first time in 1967 in severely defoliated stands on the St. Joe National Forest, Utah. Radial growth declined over 90 percent during the period 1962-1967. At the present high level of infestation, considerable tree mortality seems probable.

Aspen defoliation caused by the large aspen tortrix, Choristoneura conflictana, occurred over a 10,000 square mile area in interior Alaska in 1967. Temperatures as low as -40°F. during the winter of 1966-1967 did not significantly affect larval survival. However, a population decline did occur as a result of starvation in areas where complete defoliation had taken place in 1966 and large populations of larvae were present at an early stage of bud expansion in 1967. Many larvae forced to feed on other tree species failed to survive, while others experienced a reduction in pupal weight, adult size, and fecundity. No aspen mortality was observed, but radial growth of fully defoliated trees was reduced by 50 percent.

Studies of the mating activities of Atta texana indicate that late broods of workers of this ant are reared in the lower nest cavities during the winter, and worker broods are reared in the upper cavities in the spring. Winged adults appear in early April, but swarming does not occur until late May.

Flights generally are preceded by a rainfall of at least 7mm and a minimum temperature of 16°C. Flight activity begins regularly about 20 minutes before dawn.

3. Borers and tip-feeding insects. Flight and dispersal of the white-pine weevil were checked following releases of marked specimens. Beetles were recaptured throughout a plantation up to 330 feet from the release point. Taller trees and those with longer and thicker leaders were visited most frequently by the weevils.

The southwestern pine tip moth, Rhyacionia neomexicana, is considered the most important and urgent insect problem on the National Forest of Arizona. Recent life history studies have shown that the insect overwinters in the pupal stage under the surface soil and litter at the base of the tree. Adults begin to emerge in late March, peak emergence occurring in late April-early May. Eggs are laid on the inner surface of the previous year's needles. Tip moth larvae feed on expanding terminal and lateral shoots from about mid-June to mid-July, then travel down the stem to pupate in the soil. The commercial production of ponderosa pine on cutover areas and burns in northeastern Arizona may be dependent on successful control of this insect.

Wood-boring insects are often attracted to fire-killed timber, causing deterioration and lumber degrade in salvaged trees. The incense-cedar wood wasp, Syntexis libocedrii, heavily infested sapling and pole-sized incense-cedars in a burned area in California. The capacity of this insect to produce large populations and attack merchantable timber indicates that it is a potential economic threat to fire-killed cedar.

4. Sucking insects. Examination of bracted balsam fir in Shenandoah National Park, Virginia, and Fraser fir near Mt. Mitchell in North Carolina showed marked differences in the symptomology of infestation by the balsam wooly aphid. The principal injury to balsam fir was gouting of nodes and buds. Dying of branches began at the tops of trees and proceeded toward the base; infested trees generally survived. Fraser fir suffered primarily from stem infestation. Branch mortality began at the base of the crown and proceeded to the top; infested trees died in 2 to 6 years.

The balsam wooly aphid has proved to be a key factor in the establishment and survival of subalpine fir in the high-elevation forests of the Pacific Northwest. Tree mortality following infestation is frequently severe. The effect of the aphid is most significant in pioneer situations -- avalanche areas, lava beds, etc. -- where subalpine fir is often the only tree species present.

Studies of the impact of tuliptree scale feeding on yellow-poplar in Ohio have demonstrated that the insect, when numerous, can remove more than 4 times the carbon normally assimilated by a 15-foot tree. Carbon losses of

27 percent result in twig mortality, and sustained losses at this level for three years will kill the tree.

5. Cone and seed insects. Four insect species -- Eucosma vescissorinna, Dioryctria abietella, Conophthorus monticolae, and an unidentified cedidomyiid -- destroy many cones and seeds of western white pine in northern Idaho. Seed losses increase as spacing intervals between trees increase. This stand density-seed loss relationship is important, therefore, in planning and managing seed production areas of this tree species to achieve optimum yields.

Conophthorus ponderosae and Laspeyresia miscitata regularly cause serious damage to ponderosa pine cones in California. C. ponderosae kills the cones while constructing egg galleries from late May or early June through late summer. L. miscitata deposits eggs on the cone peduncle beginning in early April. The larvae bore into the cone and mine the seeds. Overwintering takes place in the pithy core of the cone and miscitata adults develop in the spring. Control measures involving the use of contact or systemic insecticides during the spring attack period will be required if satisfactory seed yields are to be obtained. Four other species -- Laspeyresia piperana, Dioryctria auranticella, Leptoglossus occidentalis and Dichelonyx crotchi, -- are also capable of severely damaging cones and reducing seed yields in California ponderosa pines. However, they occur spordically and seldom cause serious loss.

Investigations into factors regulating the severity of cone damage in the North Central States show that populations of the insects involved vary directly with the size of cone crops. The kinds of insects that predominate are those most responsive to fluctuations in cone numbers. Of the various pests, Conophthorus resinosae and Laspeyresia toreuta adapt themselves most readily to changes in cone crop size.

6. Bark-feeding insects. Life history studies of pales and pitch-eating weevils have revealed oviposition habits, period of larval and pupal development, larval and adult feeding habits, and length of life in the various stages in the Southeast. This information will be used in formulating silvicultural control measures for these serious pests of pine seedlings.

B. Biological Control

1. Invertebrate parasites and predators. The life history and habits of the introduced predator Aphidecta obliterata were studied in North Carolina. The life cycle of this insect and that of the spring generation of the balsam woolly aphid were well synchronized, a necessary prerequisite for effective biological control. Feeding studies revealed a direct correlation between larval size and daily host egg consumption. Larvae of another imported beetle, Laricobius erichsonii, were found actively feeding on aphid progeny on scattered, very lightly infested Fraser fir at eight release sites in the

Mt. Mitchell area. The ability to search for and find hosts in sparse numbers also is an important factor for effective predation.

The identity, rate of infestation, and abundance of nematode parasites of the Douglas-fir beetle were determined in widely separated beetle populations in Idaho and Utah. Ectoparasites were primarily Mikoletzkya sp. but included some Ektaphelenchus obtusus and Aphelenchoides sp. Endoparasites in the body cavity were Contortylenchus reversus and Parasitaphelenchus sp., while Parasitorhabditis obtusa occurred in the midgut. Sphaerulariopsis dendroctoni was also found in the beetle. About 93 percent of the beetles were infested with at least one nematode species. Rates of parasitism varied little by sex, greater differences occurring between localities, standing and felled trees, and age of beetles.

Nematode parasites of the genus Contortylenchus were consistently more effective than those of the genus Parasitylenchus in reducing egg production of Ips. sulcifrons in limited laboratory tests. Many of the immature stages of the beetle also were killed by Contortylenchus.

Encouraging results were obtained in preliminary laboratory tests of the nematode DD-136, Neoaplectana sp., against healthy southern pine beetle adults and immature stages in pine bolts. Nematodes in 0.1 percent formalin sprayed on the bolts penetrated the bark and infested an average of 45 percent of the sampled brood.

Egg parasitism of the fall cankerworm by Telenomus alsophilae occurs in western Virginia from early November to early December soon after host eggs are deposited. Parasites overwinter in the host and peak adult emergence occurs in mid-June, three to five weeks after all of the cankerworms have hatched.

Field and laboratory studies of the large aspen tortrix in interior Alaska in 1966-1967 revealed that six larval parasites caused from 5 to 22 percent mortality of larvae surviving to the last instar and/or pupal stage. This imposed a stress on the tortrix population, particularly in areas where the food supply of the defoliator was severely depleted and larvae were starving.

Intensive studies have been underway to determine factors affecting the success of Apechthis ontario and Itoplectis 4-cingulatus, solitary pupal parasites which attack such important defoliators as the spruce budworm and hemlock looper. Atmospheric humidity exerts an important influence on the activity and reproduction of both species. Female production and survival is favored by moderate oviposition temperatures (75° - 80° F.) for A. ontario and by lower temperatures (66° - 68° F.) for I. 4-cingulatus. Female eggs, rate of parasitization, and periods of restricted host availability cause shifts in the sex ratios of progeny from mated females. By careful manipulation, parasite survival and percent of female progeny may be significantly improved.

Parasitism of the larch casebearer by Agathis pumila in Idaho increased from 17 percent in 1966 to 25 percent in 1967 in one area where mated females had been released in 1960. An additional 10 percent reduction in the casebearer population was caused by 10 species of native parasites. Casebearer populations declined in this locality in 1967, but there was little evidence of spread of the parasite outward from the release site. Elsewhere in the region, an estimated 850,000 A. pumilis were distributed in 167 casebearer infestation areas.

In east Texas, 26 species of hymenopterous parasites have been found associated with the southern pine beetle. Nine are confirmed parasites of this beetle and Ips. engraver beetles. Because of low numbers of many species, their irregular occurrence during the year, and a lack of host specificity, most of the parasites are not effective in reducing beetle populations. Roptocerus xylophagorum, Dendrosoter sulcatus, Heydenia unica, and Coeloides pissodes seem to have the best potential for use in biological control because of the synchronization of their life cycles with those of the bark beetles and their relative abundance and widespread distribution.

2. Vertebrate predators. At least 13 species of wood borers in living southern hardwoods are preyed upon by woodpeckers. Limited counts indicate that approximately one-third of the grubs of Goes tigrinus and G. pulverluentus are destroyed in this way. Counts made at two locations for Saperda calcarata showed losses of 13 to 65 percent. Eighty-six percent of the trees infested by Dorcaschema species were worked over by woodpeckers. Predation was usually greatest on small diameter trees during late fall through early spring.

3. Insect pathogens. A satisfactory liquid fermentation process has been developed for producing Bacillus thuringiensis var. thuringiensis spores and crystals for separation in a polymer phase system. Clear separation of the spores and crystals permits more exact determination of the modes of action of each in infected insects.

Hemolymph protein patterns in acrylymide gels have been studied in an attempt to identify the proteins in normal versus diseased insect hemolymph. Standard healthy patterns have been established for the gypsy moth and compared with diseased patterns. Preliminary patterns have been established for the European pine sawfly. This technique has considerable promise for diagnosing disease.

The first phase of a 5-year study to develop means of mass rearing the European pine sawfly for the production of large quantities of the nuclear polyhedral virus has been completed. Collections totalling 750,000 larvae were infected with the virus and maintained until death. The diseased larvae were processed and decontaminated to yield nearly 2 pounds of clean polyhedra for further laboratory and field testing.

Field and laboratory tests in Oregon have shown that aerial applications of the Douglas-fir tussock moth nuclear polyhedrosis virus can be reduced to 0.2 gals./acre without decreasing insect mortality. This demonstrates the feasibility of ultra low-volume application of microbial insecticides.

A high population of the hemlock sawfly was considerably reduced by a fungus disease during the fall of 1967 in southeast Alaska. The fungus was identified as an Entomophthorales, probably in the genus Entomophthora.

C. Chemical Control

1. Insecticides. A low volume application of technical grade malathion was tested against the larch casebearer in western larch forests in Montana. A reduction of 96 percent was effected as compared with nearly 100 percent control using the standard application of $\frac{1}{2}$ lb. malathion/gal. fuel oil/acre.

Small-scale field tests using several insecticides against the spruce budworm in Montana indicated that 2.4 ozs. of technical Zectran, 16 ozs. of technical malathion, and 16 ozs. of technical DDT gave similar control results. Average larval mortalities were 94 percent, 90 percent and 88 percent, respectively.

Investigations in 1966 and 1967 showed that Ips lecontei could be induced to attack cacodylic acid-treated ponderosa pines. However, there was considerable variation in attractiveness of the trees and in subsequent parent and brood mortality. It was found that spring and early summer poisoning with the herbicide were relatively ineffective. Trees treated from late July through August were very attractive, particularly if they were felled about one month after poisoning. Entire broods and approximately 60 percent of the parent beetles were killed in upper stems of trees treated in August. Ninety-six percent of the adults attacking the lower bole of these same trees in the fall were also killed.

A four-year study was made of the distribution patterns of Bidrin and/or its metabolites in the foliage of 13 species of hardwoods using different application methods. Distribution patterns were significantly better following root implants than following trunk implants. Results indicated that the foliage of all 13 tree species can be protected from defoliators at an individual tree cost of $.20 without environmental contamination.

During the summer of 1967, a field test was conducted of Zectran applied at the rate of 1 oz./acre for control of the spruce budworm. By using a special spray system developed by the U. S. Forest Service Equipment Development Center at Missoula, Montana, the insecticide was applied in a fine spray with a maximum drop size of 120 microns. This treatment proved as effective as previous tests with 2.4 ounces of Zectran per acre with a maximum drop size of 300 microns. It is believed that further reduction in maximum drop size to 50 microns will make it possible to use an even smaller amount of material for control of this insect.

Determinations of the persistence of Zectran sprayed at the rate of 0.15 lb. per acre to control spruce budworm indicate that residue levels drop rapidly on Douglas-fir and several common browse plants within one day after treatment. Residue levels are negligible in 1 to 4 weeks depending on the plant. This shows that there is little or no danger of accumulation of Zectran to hazardous levels in the forest ecosystem.

Granular phorate (10 percent) was safely and effectively applied by means of a specially d signed, inexpensive applicator to control the Nantucket pine tip moth in a seed orchard in Virginia. Control was significantly greater than in the checks or trees treated with Cygon using a hydraulic sprayer.

Control of the basalm woolly aphid on Fraser fir in western North Carolina was effective for three years before respraying with a 1/8 percent benzene hexachloride emulsion was considered necessary. Cost of protection was less than $50 an acre/year to protect trees valued at several thousand dollars per acre in this recreational area.

In tests on mice, tetraethylammonium chloride (TEAC) was superior to atropine sulfate as an antidote for some carbamate insecticides and nicotine. The effects of TEAC could not be determined against the carbamates Sevin and Baygon because acute oral toxicity values could not be measured. TEAC was not an effective antidote against the organophosphate parathion.

2. Chemosterilants. A preliminary study was made of the effect of two chemosterilants -- tepa and hempa -- on the fertility of Ips confusus adults. Hempa was ineffective, but tepa reduced egg hatch by 97 percent. It had little effect on longevity at the dosage used. The possibility of using the male sex pheromone and a chemosterilant jointly to attract and sterilize insects in the field shows promise.

In the development of sterilization techniques for the spruce budworm, it was found that a steady buildup of pigment granules occurred in the fat body and testicular tissues of pupae treated with tepa. This indicated a protein metabolism change in the fat body. This information has contributed to a better understanding of the mode of action of the chemosterilant.

Male carpenterworm moths were allowed to rest and crawl on a surface treated with tempa. Mating 2 to 8 hours later resulted in significantly lower egg hatch. When the interval between exposure and mating extended to 24 hours, egg viability decreased to less than 4 percent.

D. Other control methods -- host resistance, site and stand manipulation attractants

The monopterpene composition of the xylem resin of 34 pine hybrids and 14 pine species was found to have a general temporal and spatial constancy within the trees examined. Resin makeup in the hybrids was generally intermediate between that of the two parents. Pairs of full siblings were not

always qualitatively and quantitatively identical. These results extend the understanding of the monoterpene composition of pine hybrids and its role in the resistance of pines to bark beetles.

Local and regional variation in the monoterpene composition of xylem resin was studied in 4 pine species important in the bark beetle complex in California. Coulter, Washoe, lodgepole and Jeffrey pines showed no sharply distinctive regional variation. This information is basic to an understanding of the interrelationships of pines and destructive bark beetles.

The first flight response of a bark beetle to synthetic sex pheromones under natural conditions has been reported by a team of scientists from the Forest Service, University of California, and Stanford Research Institute. The synthetic material was a synergistic mixture of three terpene alcohols which were originally isolated from frass of the insect involved, Ips confusus. Two insect species predaceous on this bark beetle also responded to the attractant. The same response by flying insects was elicited to the synthetic as to the natural attractant emanating from male-infested bolts of ponderosa pine.

Extracts of attractants obtained from the abdomens of female European pine shoot moths have a short life. Carbowax 200, Carbowax 550, Carbowax 1500, Myverol and polyethylene glycol distearate incorporated at rates of 10 to 25 percent by volume with methylene chloride extracts of female abdominal tips extended the attractiveness of baits by 8 to 14 days. However, after a few days extract baits were not competitive with the natural attractant emitted by live females. Trapping for control purposes must therefore utilize live females as lures until the sex pheromone can be isolated, identified, and synthesized in quantity.

Female Dioryctria abietella cone moths produce a sex pheromone which attracts males of the species. The pheromone is produced and released after 6 to 8 hours of darkness, reaches a peak after 10 to 12 hours, and then tapers off. Males copulate with several different females on succeeding nights. Females copulate only once during an adult life of 7 to 10 days.

Studies were made of the effects of pruning and ground treatments on populations of the pine root collar weevil. Adults were able to inhabit the duff under pruned trees but laid fewer eggs. Populations were markedly reduced where the duff was removed or the ground was raked bare to mineral soil. The latter two treatments were sufficient to control the insect without using more direct methods. Pruning to snow depth combined with either duff or soil treatment should control the pine root collar weevil and European pine shoot moth and reduce the incidence of associated Scleroderris canker in infested young red, jack, and Scotch pine plantations in Michigan.

A pilot study in three northern Minnesota spruce-fir stands showed that as cutting intensity increased, defoliation by the spruce budworm decreased on the residual trees. Commercial clearcutting, a practice favored by loggers in harvesting balsam fir, is also the best method for spruce budworm hazard

reduction. This is fortunate because thus far the more costly partial cutting technique was the recommended procedure for silvicultural control of the spruce budworm in thirty pole stands. Another study showed that balsam fir regeneration may be protected from the spruce budworm by felling residual overstory host trees.

After small-scale prescribed burns showed that Conophthorus resinosae cone beetles could be killed with fire during their hibernating period in the litter, larger-scale tests were carried out to assess the effectiveness of this method. The pilot burning of 5 seed production areas resulted in successful protection of seed crops from the beetle. The method has now been put into operational use in the Lake States.

Data collected in cooperation with personnel from the Missouri Forestry Division over the past three years shows that scarlet, red, and black oaks of that State are being degraded by the same borer species as are found in Ohio and Kentucky. This means that performing TSI operations in odd-numbered years in Missouri also will reduce borer numbers and an annual resource loss by as much as $90,000 per year.

The western pine beetle was the most important source of ponderosa pine mortality over a 10-year-period on uncut control plots on the Piquett Creek Experimental Area in western Montana. Tree killing was reduced 72 percent during the same period on plots subjected to sanitation-salvage cutting. Random selection cutting, which removed a similar volume of timber, resulted in a reduction in beetle-caused mortality of only 5 percent during the same period.

E. Insect and Tree Physiology

Electrophysiological research involving Dioryctria abietella adults and extracts from slash pine conelets has been completed. Strongest antennal responses were shown for the chemical components of pine tissue, l-pinene, and d-limonene. Chloroform and carbon tetrachloride extracts of cone material also elicted strong responses.

Ovariole development and termination of diapause in adult white pine weevils of known age were studied by dissection and photographically recorded. Observations confirmed that diapause is obligatory but that temperature requirements for breaking diapause are satisfied by early November.

Significant progress has been made in understanding the nature of the bile pigment-protein complex in the hemolymph of the spruce budworm. The concentration of this chromoprotein has been found to vary from population to population, primarily with the geographical location and host. However, it is relatively constant within a population. Results of this research may indicate a means of measuring and assessing interpopulation variation in this characteristic.

Changes in hemolymph volume were studied in healthy sixth-instar larvae of Pseudaletia unipuncta following injection with living and dead Bacillus thuringiensis. The treatments caused a reduction in hemolymph volume. The hemocytic defense reaction was determined by measuring the numbers of circulating cells. Microplasmatocyte retention was favored whereas macroplasmatocytes dropped out of circulation following treatments. These results show that differential hemocyte counts are particularly suited for diagnostic purposes.

A serological comparison of Pissodes strobi and P. approximatus revealed that populations of the two weevils were indistinguishable except for a peculiar quantitative expression of antigens. This distinction was not the kind ordinarily found between valid species, so the serological evidence did not support the designation of approximatus as a separate species.

Studies of the general movement of chemicals in pines of the southeastern United States were made by injecting 31 to 35-year old longleaf, shortleaf, slash, and Virginia pines with acid fuchsin dye. The pattern of water conduction in these species was determined to be of the spiral type in which the tracheids ascend in a clockwise direction around the axis of the tree. The pattern of tracheid alignment in the branches was like that of loblolly pine in which they run parallel to the axis of the branch.

Approximately 3 to 5 percent of the fresh weight of loblolly pine inner bark is crude lipid extract. Triglycerides and free fatty acids are the major constituents with hydrocarbons, sterols and phospholipids present in smaller quantities. Gas-liquid chromatography of the combined triglycerides and free fatty acid fractions showed that palmitic, oleic and linoeic acids were the principal fatty acids present.

The inorganic constituents of over 700 inner bark samples collected from 20 to 30-year old loblolly pines growing on three soil types were determined for a 13-month period. Wet weight, nitrogen, potassium, magnesium, sodium, and iron varied with soil type and date of collection. Ash content, moisture, phosphorus, aluminum, and manganese varied principally with soil type, also. Dry weight, calcium, and copper varied mainly with month of sampling. Zinc content changed little with site or date of sampling.

F. Nutrition and Rearing

A method has been developed for infesting pine slabs or billets in the laboratory in order to evaluate various factors affecting mountain pine beetle populations. Ninety percent establishment success was achieved in the first introductions of parent beetles.

Newly hatched larvae of the smaller European elm bark beetle have been successfully reared through adulthood on an artificial medium. Adults emerged 4 weeks after larvae were placed on the diet.

Foliage-feeding and tip-infesting insects may be reared on excised conifer stems kept in water using an aseptic technique which retards the growth of microflora. Tests revealed that foliage remained fresh for an average of 5 weeks or until the foliage was consumed, whereas untreated foliage lasted only 10 days. This technique will prove most beneficial when time or availability of host material create difficult, expensive rearing situations.

An artificial diet has been developed for the forest tent caterpillar, Malacosoma disstria, in the Lake States. It has increased the number of seasonal generations and eliminated the need for a continuing source of the insect's natural food materials.

Dioryctria abietella can now be successfully reared on an artificial medium. Survival and generation time surpass that obtained with the present method of rearing in pine cones.

An improved artificial diet for the Pales weevil has resulted in higher initial larval survival and increased pupation rate and development. Comparisons between field-and diet-reared weevils revealed no differences in fat or moisture content.

In cooperative studies with University of Florida scientists, techniques were developed for determining if the presence of certain fungi and yeasts affects reproduction and brood development of Ips avulsus. Nutrients essential to development of Ips were found in pine foliage; this may facilitate mass rearing methods.

G. Survey and Sampling Techniques

A black light technique was developed for finding jack-pine budworm egg masses on foliage. When compared with fluorescent and natural light, the use of black light significantly increased the accuracy of foliage examinations. This technique will apply to spruce budworm egg mass surveys as well.

The lower third of the crown is a suitable universe for sampling overwintering populations of the western budworm, Choristoneura occidentalis. A consistently high proportion of the total larval population on the tree hibernates in this stratum. Whole-branch samples can be drawn from this level without felling the tree or jeopardizing its use for subsequent data gathering on feeding larvae, egg masses, and defoliation. More data are being accumulated on variability of larval populations per branch within and between trees of all ages and sizes in light to severe infestations.

A sequential sampling plan for classifying infestation levels and potential defoliation by the fall cankerworm according to egg mass numbers was field tested in New York, New Jersey, and Massachusetts. Egg masses were sampled in the winter months of 1966-67 and defoliation estimates made at the same points the following May. Stands in which egg mass counts indicated light

defoliation were subsequently lightly defoliated. Only two of eight stands expected to receive heavy defoliation were so affected, apparently due to unfavorable weather and unusually high egg parasitism. Accurate identifications and estimates of numbers of the mountain pine beetle were obtained from radiographs of slabs containing different stages of the beetle. Errors in identification and counts from radiographs obtained at 25 KV were less than 10 percent of the mean.

Radiography proved to be an accurate method also for detecting the immature stages of Rhyacionia tip moths and their parasites and predators within pine shoots. The X-ray technique was also effective in evaluating seed damage caused by two bugs, Leptoglossus corculus and Tetyra bipunctata, in southern pine seed orchards.

Spruce spider mite populations on Douglas-fir sprayed with DDT to control the spruce budworm have geen sampled with the Henderson-McBurnie mite brushing machine. Sampling this way is more rapid and efficient than with older conventional methods.

RPA 801 - HOUSING RESEARCH

Wood Products Insects

Several soil treatments continue to provide 100 percent protection from subterranean termites in southern Mississippi. These include: chlordane at 1.0 percent in water emulsion, 19 years; aldrin and dieldrin at 0.5 percent in water emulsion, 17 years; and heptachlor at 0.5 percent in water emulsion, 14 years. This research has provided the basis for effective protection of wooden structures throughout the world.

Similarly, after 20 years in place in a sandy loam soil, technical DDT subjected to over 100 feet of accumulated rainfall was found to have remained within 12 inches of where it was originally placed. The only movement of DDT on the soil surface was by sheet erosion and most of the DDT had been converted to the less toxic DDE.

Freshly sawn hardwood lumber can be protected during airdrying from Lyctus powder-post beetles and ambrosia beetles with a dip treatment of 5 ozs. of lindane per 50 gals. of water. This inexpensive treatment will protect high-valued oak, walnut, hickory and other hardwoods.

Studies were made at the University of Wisconsin in cooperation with the Wood Products Insect Laboratory on the response of 4 termite species to extracts from woods decayed by various fungi. Reticulitermes flavipes responded strongly to the known attractant from Lenzites trabea and somewhat less strongly to the extract from Daedalea quercina. R. virginicus responded well to both Poria monticola and P. cocos extracts. No combinations of fungus extracts elicited a response from R. flavipes but R. virginicus responded well to a mixture of P. monticolae and P. cocos.

The Formosan subterranean termite, Coptotermes formosanus, has become established in the coastal areas of the continental United States. Experience in the Orient has shown that this new species can cause severe damage more quickly than our native subterranean termites. Although not yet widespread in the United States, the insect is capable of spreading along the Gulf, Pacific, and Atlantic Coasts. Inland distribution will probably be limited to the southern part of the country by winter temperatures. Studies are underway to determine the termite's habits in this hemisphere and to develop an effective means of control.

RPA 113 - REMOTE SENSING RESEARCH

Investigations to detect previsual symptoms of tree mortality by bark beetles in the Black Hills of South Dakota have not yielded any airborne sensor which can detect dying trees before they can be seen on the ground. However, very small scale (1: 100,000) aerial color and false color films do record the presence of large infestations (20 or more trees) when the foliage becomes yellow to yellow-red. Small infestations are overlooked or appear to blend in with surrounding vegetation.

Color photography at 1:7,920 scale was worked into a double-sampling-with-stratification technique to provide a highly efficient survey of an expanding mountain pine beetle outbreak in central Oregon. Several benefits were accrued: (1) the amount and impact of the lodgepole pine killed by the insect were measured, (2) a base was established from which the trend of the outbreak and potential tree mortality could be estimated, (3) the planning and preparation of salvage sales of beetle distressed timber in relation to existing and needed road systems and logging priorities were expedited.

The use of large-scale 70 mm aerial photographs has proved to be an effective technique for detecting tree mortality in white fir stands attacked by the Douglas-fir tussock moth. High correlations were obtained between ground and photo estimates of dead white fir trees. Correlations for trees with thin tops and top kill were much lower, but this may be improved with increased training of interpreters.

Studies of the total energy budget of healthy and dying trees revealed that dying trees have temperatures 4 to 8 degrees C. higher than healthy, living ones. This difference should be detectable with high sensitivity airborne scanners.

Aerial color photography has been used to follow the trend of Fraser fir mortality in a balsam woolly aphid epidemic area in the Southeast. Amount of tree mortality was related to population trends of the insect over a five-year period. Since balsam woolly aphid damage is accumulative, equations were developed to compute the index of accumulated fir mortality.

As an aid to aerial photo interpretation, a Crown Closure Comparator has been developed. The Comparator is used to stratify 1-acre plots into broad volume classes on single aerial photos. It divides the crowns into 4 crown-diameter and 9 crown-closure classes. This device is easy to use by the photo interpreter, and it can also be used for stereo classification with mirror-type stereoscopes.

PUBLICATIONS - USDA AND COOPERATING PROGRAMS

RPA 201 - FOREST INSECTS RESEARCH

Biology and Ecology

Amman, G. D., and R. L. Talerico. 1967. Symptoms of infestation by the balsam woolly aphid displayed by Fraser fir and bracted balsam fir. U. S. Forest Serv. Res. Note SE-85, 7 pp., illus.

Amman, G. D. 1967. Effect of minus 29° F. on overwintering populations of the balsam woolly aphid in North Carolina. J. Econ. Entomol. 60: 1765-1766.

Balch, R. E., and R. G. Mitchell. 1967. Balsam woolly aphid Adelges piceae. pp. 70-74. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Batzer, H. O. 1968. Hibernation site and dispersal of spruce budworm larvae as related to damage of sapling balsam fir. J. Econ. Entomol. 61(1): 216-220.

Burns, D. P. 1967. The impact of tuliptree scale feeding on its host, yellow-poplar. Ph.d. Dissertation. The Ohio State University.

Burns, D. P. and L. P. Gibson. 1968. The leaf mining weevil of yellow-poplar. Ph.D. Dissertation. The Ohio State University.

Campbell, R. W. 1967. The analysis of numerical change in gypsy moth populations. Forest Sci. Monogr. 15, 33 pp.

Campbell, R. W. 1967. Studies of the sex ratio of the gypsy moth. Forest Sci. 13: 19-22.

Campbell, R. W. 1967. Measuring age specific mortality factors of the gypsy moth. Proc. North Central Br. Entomol. Soc. Amer. 22: 53-56.

Carolin, V. M. and R. R. Lejeune. 1967. Western hemlock looper Lambdina fiscellaria lugubrosa. Pp. 123-125. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Carroll, W. J., and W. E. Waters. 1967. Eastern hemlock looper Lambdina fiscellaria fiscellaria. Pp. 121-122. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Chansler, J. F. 1967. Biology and life history of Dendroctonus adjunctus Blandford (Coleoptera: Scolytidae). Ann. Entomol. Soc. Amer. 60(4): 760-767.

Cole, W. E., and R. F. Shepherd. 1967. Mountain pine beetle Dendroctonus ponderosae. Pp. 13-15. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

DeBarr, G. L. 1967. Two new sucking insect pests of seed in southern pine seed orchards. U. S. Forest Serv. Res. Note SE-78, 3 pp.

Donley, D. E. and D. P. Burns. 1967. The foraging behavior of the honeydew seeking ant, Dolichoderus taschenbergi Mayr. Bull. Ecol. Soc. Amer. 48(2):65-66.

Drooz, A. T. 1967. The larch sawfly. U. S. Dep. Agr. Forest Pest Leafl. 8(Rev.). 4 pp., illus.

Dyer, E. D. A., and K. H. Wright. 1967. Striped ambrosia beetle, Trypodendron lineatum. Pp. 27-30. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Eaton, C. B., and R. Rodriguez Lara. 1967. Red turpentine beetle, Dendroctonus valens. Pp. 21-24. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Eaton, C. B., and R. Rodrigues Lara 1967. California pine engraver, Ips plastographus. Pp. 25-26. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Eaton, C. B., and R. R. Lejeune. 1967. Western pine beetle, Dendroctonus brevicomis. Pp. 89-91. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Ebel, B. H., and E. P. Merkel. 1967. Hylobius weevil larvae attack roots of young slash pines. Forest Sci. 13: 97-99.

Ewan, H. E., and R. J. Finnegan. 1967. Pine root-collar weevil, Hylobius radicis. Pp. 11-113. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Fellin, D. G., and W. C. Schmidt. 1967. Spruce budworm larvae sever stems of western larch shoots in Montana. J. Forestry 65(4): 258-260, illus.

Fellin, D. G., and W. C. Schmidt. 1967. Magdalis gentilis Leconte (Coleoptera: Curculionidae) a newly discovered pest of forest regeneration in Montana. Mont. Acad. Sci. Proc. 26: 59-60.

Finnegan, R. J., and P. A. Godwin. 1967. Northern pine weevil, Pissodes approximatus. Pp. 145-147. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Foulger, A. N. 1968. Effect of aphid infestation on properties of grand fir. Forest Prod. J. 18(1): 43-47.

Franklin, J. F. and R. G. Mitchell. 1967. Successional status of subalpine fir in the Cascade Range. U. S. Forest Serv. Res. Paper PNW-46, 16 pp.

Gibson, L. P. 1968. The 1958 pine tip moth collapse in Ohio. Ann. Entomol. Soc. Amer. 61(3): 767-787.

Godwin, P. A., and W. A. Reeks. 1967. White-pine weevil, Pissodes strobi. Pp. 148-151. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Hard, J. S. 1967. Identification of destructive Alaska forest insects. U. S. Forest Serv. Misc. Paper, 19 pp.

Harman, D. M., and H. M. Kulman. 1966. A technique for sexing live white-pine weevils, Pissodes strobi. Ann. Entomol. Soc. Amer. 59: 315-317, illus.

Harman, D. M., and H. M. Kulman. 1967. Flight and dispersal of the white-pine weevil. J. Econ. Entomol. 60: 1682-1687, illus.

Harman, D. M., and H. M. Kulman. 1968. Biology and natural control of the white-pine weevil in Virginia. Ann. Entomol. Soc. Amer. 61: 280-285.

Hay, C. J. 1968. Frass of some wood-boring insects in living oak (Coleoptera:Cerambycidae; Lepidoptera: Cossidae and Aegeridae). Ann. Entomol. Soc. Amer. 61(2): 255-258.

Johnson, P. C., and D. A. Ross. 1967. Douglas-fir tussock moth, Hemerocampa pseudotsugata. Pp. 105-107. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Kangas, E., V. Perttunen, and H. Oksanen. 1967. Studies on the olfactory stimuli guiding the bark beetle Blastophagus piniperda L. (Coleoptera, Scolytidae) to its host tree. Ann. Entomol. Fenn. 33:3, Pp. 181-211. (P.L. 480 - Finland)

Koerber, W. 1967. Studies of the insect complex affecting seed production of ponderosa pine in California. Ph.D. thesis, Univ. Calif., Berkeley, 86 pp., illus.

Kulman, H. M., and D. M. Harman. 1967. Unsuccessful brood development of the white-pine weevil. J. Econ. Entomol. 60: 1216-1220.

Lejeune, R. R., and V. M. Carolin. 1967. Black-headed budworm, Acleris variana. Pp. 66-69. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Lewis, F. B., and L. Daviault. 1967. Gypsy moth, Porthetria dispar. Pp. 152-156. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Lincoln, A. 1968. Insect research at the Delaware Laboratory. Trees Magazine 28(2): 14-17.

Massey, C. L. and R. Rodriguez Lara. 1967. Roundheaded pine beetle, Dendroctonus adjunctus. Pp. 210-212. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Massey, C. L., and R. Rodriguez Lara. 1967. Larger Mexican pine beetle, Dendroctonus parallelocollis. Pp. 217-218. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Massey, C. L., and R. Rodriguez Lara. 1967. Arizona five-spined engraver, Ips lecontei. Pp. 219-220. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

McPherson, J. E., and L. F. Wilson. 1967. Grasshoppers feeding on red pine trees in Michigan (Orthoptera: Acrididae). Mich. Entomol. 1: 249-252.

Merkel, E. P. 1967. Life history of the slash pine seedworm, Laspeyresia anaranjada Miller (Lepidoptera: Olethreutidae). Fla. Entomol. 50(3): 141-149.

Miller, W.E. 1967. The European pine shoot moth--ecology and control in the Lake States. Forest Sci. Monogr. 14, 72 pp.

Miller W. E., L. F. Wilson, and R. G. Buchman. 1967. Relative infestation of European shoot moth on interplanted ponderosa and red pines in Michigan. J. Forestry 65:818-819.

Mitchell, G. 1967. Abnormal ray tissue in three true firs infested by the balsam woolly aphid. Forest Sci. 13(3): 327-332.

Moser, J. C. 1967. Mating activities of Atta texana. Insectes Sociaux 14(3): 295-312, illus.

Neunzig, H. H., and E. P. Merkel. 1967. A taxonomic study of the pupae of the genus Dioryctria in the Southeastern United States (Lepidoptera: Phycitidae). Ann. Entomol. Soc. Amer. 60(4): 801-808.

Orr, L. W., and R. Rodriguez Lara. 1967. Southern pine beetle, Dendroctonus frontalis. Pp. 213-216. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Peacock, W. 1967. Dutch Elm Disease Confr., June 29-30, Delaware, Ohio. 69 pp.

Pointing, P. J., and W. E. Miller. 1967. European pine shoot moth, Rhyacionia buoliana. Pp. 162-166. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Prebble, M. L., and V. M. Carolin. 1967. Spruce budworm, Choristoneura fumiferana. Pp. 75-80. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Rexrode, C. O. 1967. Preliminary study on the time and frequency of oak bark beetle attacks on oak wilt trees. Plant Dis. Reptr. 51: 755-757.

Schenk, J. A. and A. G. Richard. 1967. Cone and seed insects of western white pine in northern Idaho. J. Forestry 65 (3): 186-187.

Silverstein, R. M., R. G. Brownlee, T. E. Bellas, D. L. Wood and L. E. Browne. 1967. Brevicomin: Principal sex attractant in the frass of the female western pine beetle. Science 159: 889-891.

Sippell, W. L. and H. E. Ewan. 1967. Forest tent caterpillar, Malacosoma disstria. Pp. 126-129. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Solomon, J. D. 1967. Regeneration of a mandible in a larva of the carpenterworm, Prionoxystus robiniae (Lepidoptera: Cossidae). Ann. Entomol. Soc. Amer. 60(2): 481-482.

Solomon, J. D. 1968. Gallery construction by the carpenterworm, Prionoxystus robiniae, in overcup oak (Lepidoptera: Cossidae). Ann. Entomol. Soc. Amer. 61(1): 72-74.

Speers, C. F. and D. Schmiege. 1967. White grubs in forest tree nurseries and plantations. U. S. Dep. Agr. Forest Pest Leafl. 63(Rev.). 4 pp., illus.

Struble, G. R. 1967. Lodgepole needle miner, Coleotechnites milleri. Pp. 98-102. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Talerico, R. L., and G. D. Amman. 1967. Symptoms of infestation by the balsam woolly aphid displayed by Fraser fir and bracted balsam fir. U. S. Forest Serv. Res. Note SE-85. 7 pp.

Tate, L., and W. D. Bedard. 1967. Methods of sexing live adult western pine beetles. J. Econ. Entomol. 60(6): 1688-1690, illus.

Thatcher, R. C. 1967. Pine sawfly Neodiprion excitans Roh. U. S. Dep. Agr., Forest Serv. Forest Pest Leafl. 105. 4 pp., illus.

Thatcher, R. C. 1967. Winter brood development of the southern pine beetle in southeast Texas. J. Econ. Entomol. 60(2): 599-600.

Thatcher, R. C., and L. S. Pickard. 1967. Seasonal development of the southern pine beetle in east Texas. J. Econ. Entomol. 60(3): 656-658.

Thomas, H. A. 1968. A description of the pupa of the pales weevil, Hylobius pales (Herbst.) and a method for identifying its sex. Can. Entomol. 100(4): 434-437, illus.

Torgersen, T. R., and B. H. Baker. 1967. The occurrence of the hemlock looper (Lambdina fiscellaria (Guenee)) (Lepidoptera: Geometridae) in southeast Alaska, with notes on its biology. U. S. Forest Serv. Res. Note PNW-61.

Waters, W. E., and R. J. Finnegan. 1967. Pales weevil, Hylobius pales. Pp. 108-110. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Webb, F. E., and J. L. Bean. 1967. Jack-pine budworm, Choristoneura pinus. Pp. 81-83. In: Important Forest Insects and Diseases of Mutual Concern to Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Webb, F. E., and R. E. Denton. 1967. Larch casebearer, Coleophora laricella. Pp. 84-88. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Webb, F. E., and A. T. Drooz. 1967. Larch sawfly, Pristiphora erichsonii. Pp. 157-161. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Whitten, R. R., and W. A. Reeks. 1967. Native elm bark beetle, Hylurgopinus rufipes. Pp. 114-116. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Whitten, R. R., and W. A. Reeks. 1967. European pine sawfly, Neodiprion sertifer. Pp. 134-137. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Whitten, R. R., and W. A. Reeks. 1967. Smaller European elm bark beetle, Scolytus multistriatus. Pp. 167-170. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Wickman, B. E. 1967. Life history of the incense-cedar wood wasp, Syntexis libocedrii (Hymenoptera: Syntexidae). Ann. Entomol. Soc. Amer. 60(6): 1291-1295, illus.

Wickman, B. E. 1968. The biology of the fir tree borer, Semanotus litigiosus (Coleoptera: Cerambycidae) in California. Can. Entomol. 100(2): 208-220, illus.

Wilkinson, R. C., W. T. McClelland, R. M. Murillo, and E. O. Ostmark. 1967. Stridulation and behavior in two southeastern Ips bark beetles (Coleoptera: Scolytidae). Fla. Entomol. 50(3): 185-195.

Wilson, L. F. and W. A. Reeks. 1967. Introduced pine sawfly, Diprion similis. Pp. 96-98. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Wilson, L. F., and W. A. Reeks. 1967. Red-headed pine sawfly, Neodiprion lecontei. Pp. 130-133. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Wood, D. L., R. W. Stark, R. M. Silverstein and J. O. Rodin. 1967. Unique synergistic effects produced by the principal sex attractant compounds of Ips confusus (LeConte)(Coleoptera: Scolytidae). Nature, 215(5097):206.

Wood, D. L., et al. 1967. Response of Ips confusus to synthetic sex pheromones in nature. Science 159: 1373-1374.

Wollerman, E. H. 1967. The locust borer. U. S. Dep. Agr. Forest Pest Leafl. 71 (Rev.). 7 pp., illus.

Wollerman, E. H. 1967. The boxelder bug. U. S. Dep. Agr. Forest Pest Leafl. 95 (Rev.). 6 pp., illus.

Wright, K. H., and R. R. Lejeune. 1967. Douglas-fir beetle, Dendroctonus pseudotsugae. Pp. 16-20. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Wright, J. W., L. F. Wilson, and W. K. Randall. 1967. Differences among Scotch pine varieties in susceptibility to European pine sawfly. Forest Sci. 13: 175-181.

Wygant, N. D., and R. R. Lejeune. 1967. Engelmann spruce beetle, Dendroctonus obesus. Pp. 92-95. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Wygant, N. D., and R. Rodriguez Lara. 1967. Pine engraver, Ips pini. Pp. 117-119. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Yates, H. O., III. 1967. Pupae of Rhyacionia frustrana, R. rigidana, and R. subtropica (Lepidoptera: Olethreutidae). Ann. Entomol. Soc. Amer. 60(5): 1096-1099.

Yie, S. T., S. J. Hsu, and Y. I. Chu. 1966. Biological study of the more important insect-pests attacking genus Pinus introduced from the U.S.A. IV. Frass studies of pine sawfly (Nesodiprion japonica Marlatt). Plant Prot. Bull. 8(4): 35-40. (P. L. 480 - Taiwan).

Yie, S. T., S. J. Hsu, and Y. I. Chu. 1967. Biological study of the more important insect-pests attacking genue Pinus introduced from the U.S.A. VI. The study on pine tip borer Dioryctria pryeri Rogonot. Plant Prot. Bull. 9(3-4): 1-4. (P.L. 480 - Taiwan).

Yie, S. T., and S. J. Hsu. 1967. Biological study of the more important insect-pests attacking genus Pinus introduced from the U.S.A. VII. Insect parasites of the pine caterpillar, Dendrolimus punctatus Wlk. and sawfly, Nesodiprion japonica Marlatt. Plant Prot. Bull. 9(3-4): 5-14. (P.L. 480 - Taiwan).

Biological Control

Allen, D. C. 1967. A new species of Dirophanes (Hymenoptera:Ichneumondiae) parasitic on Choristoneura pinus in northern Michigan. Canad. Entomol. 99(8): 893-895.

Baldwin, P. H. 1968. Woodpecker feeding on Engelman spruce beetle in windthrown trees. U.S. Forest Serv. Res. Note RM-105.

Boss, G. D. 1967. Parasitic and other mites associated with conifer bark beetles in central and southern Rocky Mountains. M.S. Thesis, Colo. State Univ., Fort Collins, 46 pp.

Furniss, M. M. 1967. Nematode parasites of the Douglas-fir beetle in Idaho and Utah. J. Econ. Entomol. 60(5): 1323-1326.

Galford, J. R. 1967. Emergence of Entedon leucogramma from smaller European elm bark beetle larvae reared on artificial media. J. Econ. Entomol. 60(5): 1482-1483.

Harman, D. M., and H. M. Kulman. 1967. Parasites and predators of the white-pine weevil, Pissodes strobi (Peck). Univ. Maryland, Natl. Res. Inst. Contr. 323. 35 pp.

Jensen, A. D. 1967. Parasites and predators of the Engelmann spruce beetle. Mr.S. Thesis, Colo. State Univ., Fort Collins, 74 pp.

Lewis, F. B., and A. R. Hastings. 1967. Mass rearing of the European pine sawfly, Neodiprion sertifer Geoff., for the production of large quantities of the nuclear polyhedral virus. Processed. Northeast Forest Exp. Sta., Hamden, Conn. 6 pp.

Martignoni, M. E. 1967. Separation of two types of viral inclusion bodies by isopycnic centrifugation. J. Virol. 1: 646-647.

Martignoni, M. E. 1967. Book review: INSECT VIROLOGY, by Kenneth M. Smith. Academic Press, Inc., New York and London. J. Invert. Pathol. 9: 449.

Massey, C. L. 1967. Nematodes associated with tree-infesting insects: Paurodontidae new family and Misticiinae new subfamily with a description of one new genus and four new species. Can. J. Zool. 45: 779-786.

Mathur, K. C. 1967. Notes on Apistephialtes sp., an inchneumonid larval parasite of Hypsipyla robusta Moore in India. Tech. Bul. 9, CIBC, pp. 133-135. (P.L. 480 - India).

Stelzer, M. J. 1967. Control of a tent caterpillar, Malacosoma fragile incurva, with an aerial application of a nuclear-polyhedrosis virus and Bacillus thuringiensis. J. Econ. Entomol. 60(1): 38-41.

Surany, P. 1967. Basic functions in Bacillus thuringiensis affecting its mode of pathogenesis. Pp. 247-248. In: P.A. van der Laan (Ed.). Insect Pathology and Microbial Control. Proc. Int. Colloquium on Insect Pathol. and Microbial Control, North Holland Publ. Co., Amsterdam.

Szmidt, A. 1967. Studies on biological activity of various pure strains of parasites Dahlbominus fuscipennis (Zett.) and Erdoesina alboannulata (Ratz.) (Hymenoptera, Chalcididae). Ekologia Polska-Seria A, Vol. 15, No. 10: pp. 273-284. (P.L. 480 - Poland).

Talerico, R. L., and J. L. Rauschenberger. 1967. Egg parasitism of the fall cankerworm. J. Econ. Entomol. 60: 881-882.

Thomas, H. A., P. H. Darst, and M. H. Farrier. 1967. Acarine associates of the pales weevil, Hylobius pales (Coleoptera: Curculionidae). The Fla. Entomol. 50(4): 264-266.

Witter, J. A. 1967. Bionomics of Aphidecta obliterata, a predator introduced for control of the balsam woolly aphid on Mt. Mitchell, North Carolina. M.S. Dissertation, Va. Polytech. Inst., Blacksburg, Va. 91 pp., illus.

Wittig, G. 1967. Effect of heat-stable Bacillus thuringiensis-toxin on armyworms. J. Invert. Pathol. 9: 1-2.

Wittig, G. 1968. Phagocytosis by blood cells in healthy and diseased caterpillars. III. Some observations concerning virus inclusion bodies. J. Invert. Pathol. 10 (1):

Yates, H. O., III. 1967. Key to nearctic parasites of the genus Rhyacionia with species annotations. U.S. Forest Serv. Southeast. Forest Exp. Sta., 127 pp.

Chemical Control

Abedl-Wahab, A. M., and J. E. Casida. 1967. Photo-oxidation of two 4-dimethylaminoaryl methylcarbamate insecticides (Zectran and Matacil) on bean foliage and of alkylaminophenyl methylcarbamates on silica Gel G chromatoplates. J. Agr. Food Chem. 15: 479-487.

Abdel-Wshab, A. M., R. J. Kuhr, and J. E. Casida. 1966. Fate of C 14-carbonyl-labeled aryl methylcarbamate insecticide chemicals in and on bean plants. J. Agr. Food Chem. 14, 290-298.

Andrews, T. L., and R. Miskus. 1968. Tetraethylammonium chloride as an antidote for some insecticidal carbamates and nicotine in mice. Sci. 159(3821): 1367-68.

Beal, R. H. 1967. Heavy tip moth attacks reduce early growth of loblolly and shortleaf pine. U. S. Forest Serv. Res. Note So-54, 3 pp.

Bennett, W. H. 1967. Dieldrin for protecting direct-seeded longleaf pines from the white-fringed beetle Graphognathus perigrinus (Buchanan). J. Econ. Entomol. 60(4): 1186.

Buffam, P. E., H. E. Meyer, and R. P. Miskus. 1967. Small-scale trials of five insecticides sprayed on spruce budworm in Montana. U.S. Forest Serv. Res. Note PSW-159, 4 pp.

Denton, R. E. 1967. Low-volume application of malathion for controlling larch casebearer. Mont. Acad. Sci. Proc. 26: 58.

Donley, D. E. 1967. Distribution of Bidrin in the foliage of treated trees. J. Econ. Entomol. 60(6): 1583-158.

Flake, H. W., Jr., and R. L. Lyon. 1967. Insecticide tests against larvae of Hemerocampa n. sp., a tussock moth that defoliates boxelder in New Mexico. J. Econ. Entomol. 60(2): 607-608.

Himel, C. M., and A. D. Moore. 1967. Spruce budworm mortality as a function of aerial spray droplet size. Sci. 156(3779): 1250-1251.

Kuhr, Ronald J., and J. E. Casida. 1967. Persistent glycosides of metabolites of methylcarbamate insecticide chemicals formed by hydroxylation in bean plants. J. Agr. Food Chem. 15: 815-824.

Lang, J. M., and R. P. Miskus. 1967. Zectran fed orally to mice. U. S. Forest Serv. Res. Note PSW-140. 3 pp.

Larson, J. E., G. R. Pieper, and H. C. Ratsch. 1967. Systemic activity of Zectran, Matacil, and Bidrin injected into conifer trunks. Pesticides Monitoring J. 1: 49-53.

Lyon, R. L., and P. J. Shea. 1967. Chemosterilants to control bark beetles --tepa shows promise in preliminary test. U.S. Forest Serv. Res. Note PSW-139. 5 pp.

Menn, J. J., and R. P. Miskus. 1967. Principles of pesticide metabolism studies. In: Analytical methods for pesticides, plant growth regulators and food additives. Vol. 5, Ch. 5. Academic Press Inc., New York.

Millers, I., and H. O. Batzer. 1968. Jack-pine budworm control with low-volume Malathion. N. Cent. Br., Entomol. Soc. Amer. Proc. 22: 149-150.

Oonithan, E. S., and J. E. Casida. 1968. Oxidation of methyl- and dimethylcarbamate insecticide chemicals by microsomal enzymes and anti-cholinesterase activity of the metabolities. J. Agr. Food Chem. 16: 28-44.

Pieper, G. R., and R. P. Miskus. 1967. Determination of Zectran residues in aerial forest spraying. J. Agr. Food Chem. 15: 915-916.

Smith, R. H. 1967. Lindane in diesel oil prevents western pine beetle attacks for at least one year. J. Econ. Entomol. 60(6): 1746-1747, illus.

Smith, V. K. 1968. Lindane controls Lyctus powder-post beetles during air-drying of rough ash lumber. J. Econ. Entomol. 61(1): 323-324, illus.

Yates, H. O., III. 1967. Larval migration of Rhyacionia spp. on pine shoots (Lepidoptera: Olethreutidae). J. Ga. Entomol. Soc. 2(2): 37-41.

Other Control Methods

Batzer, H. O. 1967. Spruce budworm defoliation is reduced most by commercial clear cutting. U.S. Forest Serv. Res. Note NC-36, 4 pp., illus.

Koerber, T. W. 1967. Introduction to protection problems in young-growth stands--insects. In: Confr. on Young-Growth Forest Mgt. in Calif. Proc. 1967: 120-123. Univ. Calif. Agr. Ext. Serv., Berkeley.

McCambridge, W. F. 1967. Nature of induced attacks by the Black Hills beetle, Dendroctonus ponderosae (Coleoptera: Scolytidae). Ann. Entomol. Soc. Am. 60(5): 920-928, illus.

Miller, W. E. and A. H. Taylor. 1968. How to control red pine cone beetle. U.S. Forest Serv., North Central Forest Exp. Sta., unpaged folder, illus.

Moser, J. C., and R. M. Silverstein. 1967. Volatility of trail marking substance of the town ant. Nature 215(5097): 206-207.

Smith, R. H. 1967. Variations in the monoterpene composition of the wood resin of Jeffrey, Washoe, Coulter, and lodgepole pines. Forest Sci. 13(3): 246-252, illus.

Smith, R. H. 1967. Monoterpene composition of pine species and hybrids--some preliminary findings. U.S. Forest Serv. Res. Note PSW-135, 14 pp., illus.

Wilson, L. F. 1967. Effects of pruning and ground treatments on populations of the pine root collar weevil. J. Econ. Entomol. 60: 823-827.

Wood, D. L., L. E. Browne, W. D. Bedard, P. E. Tilden, R. M. Silverstein, and J. O. Rodin. 1968. Response of Ips confusus to synthetic sex pheromones in nature. Sci. 159(3821): 1373-1374.

Insect and Tree Physiology

Asher, W. C. 1968. Response of pine seedlings to mechanical stimulation. Nature 217: 134-136.

Harman, D. M., and H. M. Kulman. 1967. Ovariole development in the white-pine weevil, Pissodes strobi. Ann. Entomol. Soc. Amer. 60: 1146-1150, illus.

Shen, S. K., and A. A. Berryman. 1967. The male reproductive system and spermatogenesis of the European pine shoot moth, Rhyacionia buoliana (Lepidoptera: Olethreutidae), with observations on the effects of gamma irradiation. Ann. of Entomol. Soc. of America, 60(4): 747-774.

Silverstein, R. M., J. O. Rodin, and D. L. Wood. 1967. Methodology for isolation and identification of insect pheromones with reference to studies on California five-spined Ips. J. Econ. Entomol. 60(4): 944-949.

Insect Nutrition and Rearing

Cole, W. E., and C. Weenig. 1967. A technique for inducing attacks and mating of the mountain pine beetle, Dendroctonus ponderosae (= monticolae) (Coleoptera: Scolytidae). Ann. Entomol. Soc. Amer. 60(4): 857-858.

Galford, J. R. 1967. A technique for rearing larvae of the smaller European elm bark beetle on an artificial medium. J. Econ. Entomol. 60(4): 1192.

Germain, C. J. and N. D. Wygant. 1967. A cylindrical screen cage for rearing bark beetles. U.S. Forest Serv. Res. Note RM-87, 4 pp., illus.

Sampling Techniques and Evaluations

Cole, W. E. 1967. Sampling biologically in forest insect populations. Ann. Entomol. Soc. Amer. 60(4): 860-861.

Ebel, B. H. 1967. Piedmont hardwoods -- which do wood borers damage? South. Lumberman 215(2680): 113-114.

Fellin, D. G. 1967. Sampling mites on Douglas-fir foliage with the Henderson-McBurnie machine. J. Econ. Entomol. 60(6): 1743-1744.

Lund, H. G., G. R. Fahnestock, and J. F. Wear. 1967. Aerial photo interpretation of understories in two Oregon oak stands. U.S. Forest Serv. Res. Note PNW-58, 6 pp., illus.

Wickman, B. E. 1967. Evaluating the impact of insects in young-growth stands. In: Confr. on Young-Growth Forest Mgt. in Calif. Proc. 1967: 127-130. Univ. Calif. Agr. Ext. Serv., Berkeley.

Yates, H. O., III. 1967. Radiographic detection of Rhyacionia larvae, pupae, parasites, and predators within pine shoots (Lepidoptera: Olethreutidae). J. Ga. Entomol. Soc. 2(3): 81-85.

RPA 801 - HOUSING RESEARCH

Beal, R. H. 1967. Formosan invader. Pest Contr. 35(2): 13-17, illus.

Beal, R. H., and L. S. Stauffer. 1967. How serious the Formosan termite invasion? Forests and People 17(3): 12-13, 28, 40-41, illus.

Johnston, H. R. 1967. Update on research at USDA's Forest Service Gulfport Laboratory. Pest Contr. 35(11): 41-42, illus.

Sen Sarma, P. K., and P. N. Chatterjee. 1966. Tolerance of pseudoworkers of Neotermes bosei Snyder (Insecta: Isoptera: Kalotermitidae) to prolonged starvation. Science and Culture, Vol. 32, p. 472. (P.L. 480 - India).

Sen Sarma, P. K. and P. N. Chatterjee. 1966. The effect of preconditioning on the humidity reactions of workers of Microcerotermes Beesoni Snyder (Isoptera, Termitidae) Insects Sociaux. 13(4): 267-276. (P.L. 480 - India).

Smythe, R. V., H. C. Coppel, and T. C. Allen. 1967. The responses of Reticulitermes spp. and Zootermopsis angusticollis (Isoptera) to extracts from woods decayed by various fungi. Ann. Entomol. Soc. Amer. 60(1): 8-9.

Smythe, R. V., H. C. Coppel, S. H. Lipton, and F. M. Strong. 1967. Chemical studies of attractants associated with Reticulitermes flavipes and R. virginicus. J. Econ. Entomol. 60(1): 228-233.

RPA 113 - REMOTE SENSING RESEARCH

Aldrich, R. C. 1967. Stratifying photo plots into volume classes--by crown closure comparator. U.S. Forest Service Res. Note PSW-151, 2 pp., illus.

Aldrich, R. C. 1968. Remote sensing and the forest survey--present applications, research, and a look at the future. Proc. Fifth Symposium on Remote Sensing of Environment. Inst. of Sci. and Tech., Univ. of Michigan.

Aldrich, R. C. and A. T. Drooz. 1967. Estimated Fraser fir mortality and balsam woolly aphid infestation trend using aerial color photography. Forest Sci. 13(3): 300-313.

Heller, R. C. 1968. Previsual detection of ponderosa pine trees dying from bark beetle attack. Proc. Fifth Symposium on Remote Sensing of Environment. Inst. of Sci. and Tech., Univ. of Michigan.

Heller, R. C., W. F. McCambridge, R. C. Aldrich, and F. P. Weber. 1967. The use of multispectral sensing techniques to detect ponderosa pine trees under stress from insect or pathogenic organisms. Second Ann. Prog. Rpt. Available in microfiche from NASA, Washington, D. C. Scientific and Technical Aerospace Reports.

Wear, J. F. 1967. Aerial color photos identify beetle-infested lodgepole pine. Forest Industries, pp. 56-57.

Wear, J. F. 1967. The development of spectro-signature indicators of root disease on large forest areas. Ann. Prog. Rept. Available in microfiche from NASA, Washington, D. C. Scientific and Technical Aerospace Reports.

Weber, F. P. and C. E. Olson. 1967. Remote sensing implications of changes in physiologic structure and function of tree seedlings under moisture stress. Ann. Prog. Rept. Available in microfiche from NASA, Washington, D. C. Scientific and Technical Aerospace Reports.

FOREST DISEASES

USDA and Cooperative Program

Location of Intramural Work	Scientist Man-Years F.Y. 1968			
	Research Problem Area			
	202	214	801	Total
California	5.0			5.0
Colorado	4.0			4.0
Connecticut	4.0			4.0
Georgia	4.0			4.0
Idaho	3.8			3.8
Maryland	4.0			4.0
Michigan	2.0			2.0
Mississippi	5.8		0.2	6.0
Minnesota	3.7			3.7
Nebraska	1.0			1.0
New Mexico	2.0			2.0
North Carolina	8.0	2.0		10.0
Ohio	5.0			5.0
Oregon	8.0			8.0
Utah	1.7			1.7
Total	62.0	2.0	0.2	64.2

Intramural program is supplemented by extramural support representing (a) 0 SMY's at State Agricultural Experiment Stations, (b) 0 SMY's at other U.S. institutions, and (c) P.L. 480 funds in eight countries representing 77,991 U.S. dollars equivalent.

Problems and Objectives

All forest trees species are subject to disease. Forest diseases cause losses to timber estimated at 5 billion cubic feet of growing stock annually, including 20 billion feet of sawtimber or about 92 percent of net sawtimber growth. Disease losses in trees and shrubs important for forage, recreation and watershed values are also serious. In addition, disease agents reduce the value of wood products in use by an estimated 300 million dollars per year. Research must find ways to reduce these losses if we are to meet the ever-increasing demands for timber, water, wildlife, recreation and esthetic values from the nation's forests.

Major objectives of the research are:

1. Determine causes of disease
2. Determine biology, ecology and physiology of the causal agents
3. Determine factors affecting spread and prevalence
4. Develop effective controls

Progress--USDA and Cooperative Program

RPA 202 - CONTROL OF DISEASES OF FOREST TREES

A. Seed and seedling diseases

Two fungi associated with cankering and twig dieback of yellow birch seedlings have been identified and shown to be pathogenic. Both are believed involved in frequent regeneration failures of yellow birch in the Lake States. Research to develop controls is in progress.

For the past 15 years at the Marrietta State Nursery in Ohio, production records indicate a consistent loss in 1- and 2-year-old beds of eastern white pine seedlings. In 1965, approximately 3 million seedlings were killed. Although numerous fungi were isolated from affected seedlings, only one produced symptoms similar to those observed in nursery beds. A positive correlation was established between low air temperature and disease severity.

It is difficult to test fungicides for control of brown spot needle blight because pine seedlings cannot be artificially inoculated with the causal fungus. In Mississippi a consistent association of another fungus spore with the spores of the brown spot fungus was observed. It is probable that both fungi combine to produce the disease symptoms and that inoculation methods may be developed.

The fungus Scleroderris lagerbergii continues to cause severe damage in red and jack pine plantations of Upper Michigan and northern Wisconsin. A manzate spray program has been recommended and put into use by several nurseries to protect nursery stock from this disease. Available evidence indicates that this spray program also substantially reduces damage to red pine in nurseries of this region from an associated disease of unknown cause.

Nursery production of skunkbush sumac and buffaloberry has been hampered by leaf spot diseases. Good control was obtained with Maneb or Captan in an eastern Nebraska nursery. Both shrubs are important soil-stabilizing species in the shelterbelts of the Great Plains.

In California, fall application of two soil fumigants in nursery seed beds reduced mortality of white fir and ponderosa pine seedlings planted the following spring. Both fumigants lowered mortality by 50 percent and reduced the proportion of seedlings with infected roots from 100 percent in the untreated beds to 25 percent in the best of the two treatments.

Studies of outplanted white fir infected with Macrophomina phaseoli, the cause of charcoal root disease, indicate that forest environments are not favorable sites for the establishment of this fungus. In similar plantings in agricultural soil the fungus was able to maintain a high population in the roots of white fir. Thus, fears of introducing the fungus to the forest from the nursery are not warranted.

Heavy damping-off losses of sweetgum seedlings in a Mississippi nursery were determined to be caused by Pythium sylvaticum. This is the first report of pathogenicity by this fungus.

Soil samples from mountain hardwood and coniferous stands in northern Georgia, eastern Tennessee, and western North Carolina, and from the Piedmont and Coastal Plain of Georgia, South Carolina, and North Carolina were assayed for Pythium and Phytophthora species. This study demonstrated the abundance of pathogenic phycomycetes in forest soils and indicates their impact on seedling survival on certain sites.

In Poland, a P.L. 480 study of forest tree seed disease organisms showed that surface sterilization of pine, larch and birch seed failed to increase germination or survival. The same is true for short-term (less than six months) storage of oak acorns. For long-term storage of acorns fungi caused considerable reductions in germination and research to develop techniques to prevent this is underway.

The fungus Rhizoctonia solani was reported to be causing considerable losses in damping-off of many species in several nurseries in India during an extensive survey under the P.L. 480 program. This knowledge is a first step in developing effective control methods.

Observations of North American trees planted abroad were continued under the P.L. 480 program. The primary objective is to test their susceptibility to foreign pathogens in order to avoid inadvertent introductions in the future. In Poland, Yugoslavia, Columbia and Uruguay only minor diseases were observed and none which are not also present in North America. In Brazil, however, serious losses to slash and loblolly pines occurred in one location, but the cause has not yet been determined.

B. Root diseases

1. Annosus root rot. Lack of a greenhouse inoculation technique has hampered pathogenicity studies on F. annosus. In the past year, however, one technique tested resulted in 70-100% mortality of inoculated seedlings. In a preliminary study, there appeared to be no variation in pathogenicity on loblolly pine among eight isolates of the fungus from North and South Carolina. Perfection of the seedling inoculation technique will allow critical studies of variation in susceptibility of different tree species and of relative pathogenicity among isolates of F. annosus.

To determine possible differences in the rate of spread in loblolly and slash pine plantations on different soil types, infection centers were established in nonthinned plantations by inoculating four stumps in the center of 0.1-acre plots. Plots were established in plantations on sandy Coastal Plain soils and on heavy clay Piedmont soils in the Southeastern United States. After nearly 3 years, 70% of the plots on sandy soils and 60% of the plots on heavy clay had dead or infected trees. It has been generally concluded that F. annosus was not a problem on heavy clay soils; but these results suggest this is not true.

In studies on direct infection of stump roots of southern pines by spores of F. annosus, levels of only 40 conidia per inoculation point on non-wounded roots resulted in 4% root infection, while on wounded roots 40 conidia produced infection in 48% of the roots. These studies indicate the relatively small number of spores capable of causing direct infection of roots and that wounded roots are more susceptible to infection.

In studies initiated in 1961, mortality from F. annosus was curtailed where prescribed burning preceded initial thinning of southern pine plantations. In an attempt to determine the reason for the reduced mortality and to determine the effects of burning on soil microflora, numbers and kinds of soil fungi and numbers of bacteria and actinomycetes were studied. No differences were found between burned and unburned soils in total numbers of the three groups of micro-organisms surveyed. However, numbers of fungi in the genus Trichoderma, which were rarely isolated from unburned soil increased considerably immediately following burning. This high post-burn level has been maintained for more than a year. Trichoderma species have been reported to be antagonistic to several pathogenic soil-borne fungi and may contribute to reduced losses by F. annosus in burned plantations.

Several factors influence the infection of stump surfaces by F. annosus basidiospores and subsequent spread of the fungus to roots of adjacent trees. Previous studies have indicated that temperatures at the stump surface reach levels lethal to the fungus during several months of the year in the Southeast. Another important factor may be seasonal variation in dispersal of spores. Data thus far indicate that high numbers of spores are present in Virginia and North Carolina beginning in September; however, high spore counts did not occur in South Carolina, Georgia, and Florida until November.

The rate of spore deposition fluctuated considerably during the fall and winter months, but several areas had high counts until March, when the rate appeared to decrease. Information on spore dispersal will help predict the time of year when stump infection by F. annosus is most likely.

A numerical rating by which Polish planting sites can be classified according to infection hazard from F. annosus has been developed in a P.L. 480 study. The rating is based on the ratio of beneficial soil organisms to total soil microflora. Healthy stands have ratios of 5000+ while badly infested stands are lower than 1000. High hazard sites are defined as those with ratios lower than 2000 and conifer plantings should be avoided on these.

2. Poria weirii root rot. In the Pacific Northwest, previous studies have shown that red alder, a native, nitrogen-fixing hardwood may discourage P. weirii by enriching soil with nitrate, a form of nitrogen favoring competing soil microbes. Field tests show that survival of P. weirii in buried wood cubes is reduced under alder as compared to conifer stands. Disease development also may be discouraged by phenolic compounds present in alder. Two isolates of the fungus were tested in liquid culture using 25 different phenolic compounds. Several inhibited the fungus completely. Research is now underway to determine the existance of these or other fungitoxic phenols in roots of red alder and Douglas-fir.

3. Other root diseases. Studies of a root rot of southern hardwoods caused by the fungus, Corticium galactinum showed that American sycamore, sweetgum, Nuttal oak, and white oak were much more susceptible to infection than green ash and water oak. The fungus did not affect mimosa. These data indicate the possibility of control through changes in stand composition.

Studies of the host range of the fungus, Verticicladiella wagenerii in the Pacific Southwest show that all pines tested, Douglas-fir, and bigcone spruce are susceptible while red and white fir are resistant. In cross pathogenicity tests between pine and Douglas-fir isolates no sign of host specificity could be detected. Maximum mortality of 90 percent occurred at 16°C and none occurred at 27°C or higher. In the host, the fungus was confined to the nonliving mature tracheids and appears similar in many respects to the vascular wilts.

In the Northeast, a Verticicladiella species was identified as the causal agent of a root decline disease of eastern white pine trees in 3- to 15-year-old plantations in Indiana, Kentucky, Maryland, Pennsylvania, West Virginia and Ohio.

4. Mycorrhizae. In the Northwest, two forms of Poria terrestris, a fungus closely related to destructive root pathogens, have been found associated with Douglas-fir mycorrhizae. Each form has a distinct mycorrhiza and growth development on artificial media. One form, having an orange-stained, white sporophore, produces an antibiotic substance in culture. The other with a lavender-stained, white sporophore, does not produce an antibiotic. It is

believed that this is the first report of two forms of the same fungus species, each forming a distinct tree mycorrhiza.

Fungi described in Europe often occur in America also but under different names. This situation has caused a great deal of confusion in identifying fungi and hindered effective collaboration between American and European researchers. Progress is being made to correct this dilemma in the order, Tuberales, a group of mycorrhizal fungi which could be important factors in protecting tree roots from disease. At least 24 species (compared to only 12 one year ago) are now known to occur on both continents. An additional 11 North American species have very close relatives in Europe. Clarification of species between the continents will allow us to draw more heavily upon knowledge accumulated through years of study by European workers.

5. Nematodes. Mortality following the frequent droughts in marginal ponderosa pine stands of Arizona and New Mexico is believed to result from plant-parasitic nematode activity during the time the trees were under a water deficit stress. The first step in investigating this problem has been to determine the nematodes endemic to the forest soils in marginal ponderosa pine stands under normal conditions. Thirty plant-parasitic nematode species, representing 14 genera, were found. They were slightly more abundant in non-drought stands than in drought stands and more abundant on junipers than pines.

One nematode, Aphelenchoides sp., that feeds on fungi was found to be prevalent in soils of marginal ponderosa pine stands in central New Mexico. The effects of its feeding on mycorrhizal and pseudomycorrhizal fungi were studied. Results showed that the nematode feeds on some fungi so heavily that the fungus is killed. Other fungi are held in check, but not killed. It is postulated that this nematode feeds so heavily on mycorrhizal fungi during periods of drought that the fungi are either killed or their growth so reduced that the tree is weakened and becomes susceptible to insect damage, root diseases, or other causes of mortality.

Studies on the pathogenicity of specific nematodes in the South proved that the sting nematode is highly damaging to sycamore, pine cystoid nematode is pathogenic to longleaf pine seedlings, and that cottonwood and red maple are hosts for stunt nematodes. Nematocidal soil treatments prior to planting longleaf pine seedlings stimulated early height growth. However, growth improvement was too small to justify economically.

A compilation from the literature listing the worldwide distribution of plant-parasitic nematodes associated with forest trees was completed. The publication includes three sections: (1) Distribution of nematodes and tree species with which they are associated; (2) A cross reference of material in section one listing tree species with all nematodes associated with each; (3) A literature cited section containing 237 readily available records selected for convenience. This publication is of great value to researchers in forest nematology.

C. Stem diseases

1. Native rusts of conifers. A white-spore race of the western gall rust fungus is widespread on ponderosa pine in the Rocky Mountain-Intermountain area. It is believed not to require an alternate host on the basis of field evidence and inoculations. Orange-spore Peridermium harknessii occurs within the eastern half of the albino's distribution, but is not known in the western half. Relatively high temperature appears to favor germination of the aeciospores of the white-spore race. Damage has been minor, thus far.

Fifteen Peridermium species were recognized in a monograph of the aecial stages of the pine stem-rust fungi. Keys and descriptions provide a means of recognizing these fungi and will help coordinate worldwide efforts to control pine stem-rusts.

Studies of the pathological histology of six canker rusts in pines revealed distinguishing features of hyphae and haustoria that can aid in identification of casual fungi even when sporulation is absent. Hyphae of all six rust fungi occurred between cells in the bark and wood, but the more elongate cankers were caused by longitudinal spread of hyphae within tracheids.

Gymnosporangium rust fungi cause leaf necrosis, galls, cankers, and witches'-brooms in juniper, cypress, incense cedar, and their alternate rosaceous hosts in the West. Descriptions and keys were developed to aid in the identification and evaluation of the importance of juniper rusts in the Great Basin region.

Cronartium conigenum causes cone rust and stem galls on at least 18 species of hard pines in southern Arizona, Mexico, British Honduras, Guatemala, Honduras, and Nicaragua. Peridermium mexicanum, the name previously used for the fungus in stem infections, appears not to be distinct from the cone-infection form. By modifying apical meristems the fungus gives rise to a great variety of gall shapes and causes profound shifts in composition of host tissues. Cone infections prevent formation of seed, and trunk infections preclude normal harvests and utilization of wood. Although widespread, this rust plays only a relatively minor role in restricting regeneration of pine stands.

Rather than being restricted to parasitizing members of the family Rosaceae, as previously believed, Phragmidium rust was also found on violet in Idaho and on a grass in California.

Comandra rust, caused by Cronartium comandrae, is common and moderately damaging on ponderosa pine in the Pacific Northwest. The disease is often overlooked or confused with other causes of damage. Cankers in lower crowns are immediate threats to young-mature trees, but rust-killed tops in old-growth timber are not necessarily indicative of high-risk trees. The rust is of slight importance in unthinned stands and damage in thinned stands can be reduced by careful selection of crop trees.

Analysis of available information indicates that grazing by sheep reduces rather than increases the abundance of comandra, the alternate host of comandra rust, and that overgrazing probably did not contribute to the intense damage reported in the 1950's of comandra rust in lodgepole pine in the Rocky Mountains.

In the Lake States, stalactiform rust causes its most serious damage in nurseries. Juvenile trees are highly susceptible and infection usually causes death. Mortality in pole-size and larger trees is rare. Little decay is found behind the cankers on older trees. At present, this disease is not widespread in Lake States stands.

2. White pine blister rust. Blister rust resistant F_2 seed orchards being developed in the Intermountain Region will not produce seed until about 1985. However, through manipulation of pollination and selective cone collection in an already established research arboretum, one-sixth of the Region's annual requirements for resistant seed can be produced in the near future.

Basic studies of host-parasite physiology in blister rust continue at the Intermountain Station. Successful culture of rust-infected western white pine tissue was obtained on the same chemically defined medium used for culturing healthy pine tissue. This technique gives the researcher a tool to study host-parasite physiology in a controlled environment, and may prove to be a bridge toward establishing the rust organism in pure culture. Infected tissue cultures provide a means of evaluating the effects of physical and biological environmental factors, and of chemotherapeutants and other chemical compounds, on the host-parasite system.

The principal cell wall constituent of Cronartium ribicola is chitin, which was not detected in cell walls of its Ribes and pine hosts. Pectin predominated between cell walls in healthy pine tissue, but was not found in rust cells or in host tissues invaded by the fungus.

Evaluation of the fungus Tuberculina maxima as a possible biologic control agent for blister rust continues. It is known that the fungus can overwinter as spores, sporodochia, or endogenous mycelium on blister rust cankers. Field and laboratory inoculations of blister rust cankers on western white pine during periods of aecial production, pycnial production, and no sporulation show that cankers are susceptible to infection by T. maxima only during periods of aecial and/or pycnial production. This limited infectivity definitely hinders the potential of this organism as a biologic control agent.

Evaluations of several antibiotics and fungicides for blister-rust control were made in California. The antibiotic, Phytoactin L-340 and the fungicide Dowicide 1 (O - phenylphenol) showed the most promise for systemic chemical control of blister rust on sugar pine in northern California. Apparent effectiveness of the antibiotics rose to marked maximums 2 to 3 years after application, then declined.

Phytoactin was not an effective control for blister rust of western white pine in tests by the Intermountain Station. When applied in either aerial or basal stem treatments, the results were not significantly different from those of the nontreated controls. Another antibiotic, cycloheximide tested in a basal stem treatment, had 26 percent inactive cankers four growing seasons after treatment and was significantly different from nontreated checks, but was also considered ineffective as a practical control.

In eastern white pine in the Lake States, the antibiotics cycloheximide and Phytoactin were absorbed and translocated both upward and downward in the phloem and xylem. Cycloheximide persisted longer and in larger quantities in the tissue than did Phytoactin. Both antibiotics diminished rapidly in the tissues during the first 2 months, then more slowly for the next 2 years. Although these antibiotics did not control blister rust, the results indicate that systemic action in white pine is feasible.

Basic research continued under a Forest Service grant to the University of Wisconsin on the infection process in blister rust of eastern white pine. Many more infection vesicles were observed in primary needles of young seedlings than on secondary needles of older trees even under the most favorable infection conditions. It appears that the mechanism of this influence is independent of inherent resistance, but both affect resulting infection levels. Accumulations of wax in the stromatal cavities of older needles is believed responsible for the physiological age effect.

3. Fusiform rust. Fusiform rust infection of southern pines can be prevented by the application of fungicides prior to spore dispersal. This is economically feasible only in high value areas--nurseries and select seed orchards. Failure to apply the fungicide in time may nullify a dozen previous sprayings. Studies have defined the conditions under which infection can occur, and predictable synoptic weather patterns have been correlated with high infection periods. These findings will make spraying for rust control much more reliable.

Sodium arsenite, applied directly to the surface of the gall, has given what has been termed "chemical eradication" of established fusiform infections on field and seed orchard pines. These results have held over a period of 5 years and very little phytotoxicity has resulted from the sodium arsenite applications. At present the technique cannot be used in large-scale field operations because of economic reasons, but it is already being used in many areas of the South on high-value seed orchard trees.

In order to make maximum progress in programs designed to produce superior fusiform rust resistant pines by selection and breeding, it is necessary to determine if the natural population of the pathogen, Cronartium fusiforme, contains pathogenic strains or races. To evaluate the pathogenic capabilities of this fungus 20 species of hard pines, including most southern and eastern species as well as several exotics, were inoculated with four collections of the fungus. All gave very uniform infection results on the

pines tested. This indicates that, for the rust population sampled, there is little variation on the part of the pathogen. This work also demonstrated that pond pine, which according to earlier work was considered very susceptible to rust, was in fact resistant to infection. This offers the possibility of utilizing pond pine under conditions where loblolly and slash pines cannot be grown because of the high rust hazard.

In order to evaluate both the resistant and susceptible responses of the pines from the above study histological comparisons were made. As expected, it was found that mycelial development of the fungus was greater in the more susceptible pines and less in the resistant. However, even resistant species had considerable fungus mycelium within their tissues. In all species mycelial development was limited to the area of the pine needle visibly discolored and movement up and down the needle seemed to be rather restricted. This work has led to further experimentation to determine how important needle infections actually are in terms of subsequent stem gall development. It is possible that some pines which are susceptible to needle infection may still be essentially disease resistant due to the failure of the fungus to spread to stem tissues and form the lethal galls.

4. Canker diseases. In the Lake States, efforts are continuing to artificially infect aspen with the Hypoxylon canker fungus in a manner that could conceivably happen in nature. Presumably this will involve the use of ascospores that are transferred from a canker to a potential infection site. Because the majority of existing cankers on aspen stems are associated with branches or branch stubs, it may be that some morphological or physiological factor related to that part of a tree is more susceptible to infection.

Efforts to control Hypoxylon canker of aspen with antibiotics were unsuccessful. The test was done in an area containing 2- to 4-inch d.b.h. aspens with a moderate degree of Hypoxylon canker present. Sample trees were selected on the basis of having an established infection on the main stem. The individual materials were applied to separate plots by helicopter. Materials used were three different formulations of Phytoactin, two formulations of semicarbazone, a 20-percent oil emulsion check, and an unsprayed control. None were effective in reducing Hypoxylon mortality on the plots.

Ceratocystis cankers are one of the most damaging diseases of aspen in the Rocky Mountains. Ceratocystis fimbriata is suspected of being the causal fungus, but at least three other species are associated with the cankers. One of these has only recently been described as a new species, C. populina, Hinds & Davidson. Studies are underway to determine whether this fungus causes cankers or is a secondary parasite.

A canker disease of eastern cottonwood and hybrid poplar trees in Iowa proved to be caused by Fusarium solani. The fungus is a potential menace to all hardwoods, particularly in forest plantations.

Cytospora chrysosperma, Phomopsis macrospora, and Hypomyces solani are pathogenic on cottonwood in the South. These canker-causing fungi were most virulent in November when rains were frequent and temperatures were between 20° and 30° C. Trees growing on an unfavorable site were more susceptible than those on a favorable site.

An Ohio study of the pathogenicity of the fungus Fusarium solani to paper mulberry and white mulberry seedlings was completed. Both species were severely injured when inoculated following water stress or while dormant. Thus, the fungus appears to be a weak parasite seldom causing damage to vigorous, actively growing trees. This study reports the first occurrence and proof of pathogenicity of this fungus on paper mulberry.

An outplanting study of five areas in Upper Michigan showed that red and jack pines are more susceptible than Scotch pine to Scleroderris cankers. Mortality for 6-year-old red, jack, and Scotch pines was 82, 52, and 20 percent respectively and is expected to increase with time.

5. Dwarf mistletoes. Several factors significantly influenced infection probability of dwarf mistletoe in an Intermountain Station study. The probability of tree seedlings less than 42 inches tall being hit by seed of the parasite from overstory trees is less than 2 in 1000. Less than 1 percent of these establish infections and seed removal by snow action is the most important factor influencing this percentage. With this knowledge, guidelines for dwarf mistletoe control can be modified to allow forest managers in the northern Rockies 5 to 10 years to obtain natural regeneration beneath infested overstories (prior to their removal) without appreciable infection of the regeneration.

A California study showed that dwarf mistletoe could spread from infected overstory ponderosa pine to planted Jeffrey pine--up to a maximum distance of 145 feet. About one-third of the trees within this distance were infected after 22 years. The level of infection in the trees remained low, however, and the parasite had intensified only slightly. Dwarf mistletoe did not appear to have affected height growth. Differences in degree of infection were noted among blocks of trees from different altitudinal zones.

Most dwarf mistletoe-infected ponderosa pine stands near the south rim of Grand Canyon are within 2 miles of the rim, but the parasite extends southward at one point for about 7 miles from the rim along a broad ridge. The reason for this peculiar distribution pattern is unknown, but it could be either a reflection of climatic factors associated with the canyon rim or merely a relatively recent colonization of this area by the parasite. The forests of the Grand Canyon area represent a unique opportunity for critical studies of the ecological factors influencing the distribution of the dwarf mistletoes.

As part of their taxonomic studies of the genus Arceuthobium the Rocky Mountain Station has determined the host ranges of the various species. An intriguing result of this work is the discovery that there seems to be an interaction among the parasites. If one mistletoe species is present on a tree species it tends to exclude other mistletoe species from attacking the host in the locality. For example, the lodgepole pine dwarf mistletoe, A. americanum, is common on ponderosa pine outside the range of the typical ponderosa pine parasite, A. vaginatum, but rare within it. The reasons for this exclusion are being investigated. Discovery of why dwarf mistletoes are excluded from certain areas, might open up a whole new field of control possibilities.

In a related cooperative aid study with the University of Utah, chromosome numbers and other karyological features of Arceuthobium were determined for all species and subspecific groups in the United States and seven of the 13 entities occurring in Mexico. All had 14 chromosomes and the karyotype appeared to be fundamentally symmetrical. The existence of strong isolating mechanisms, which apparently preclude natural hybridization, is a possible explanation for the absence of polyploidy in the dwarf mistletoes. The flowering characteristics of the American species were analyzed and classified into three principal groups. These flowering groups are closely correlated with several morphological characters and seem to represent a natural basis for structuring a below-genus classification of Arceuthobium.

The white fir dwarf mistletoe, was found for the first time on the rare Brewer spruce in three localities on Siskiyou National Forest in southwestern Oregon. Damage was severe and many trees have been killed by the mistletoe. It seems to be a general rule that very rare trees, such as Brewer spruce in this instance, have little resistance to dwarf mistletoes. Because of the heavy damage it is suggested that a reconnaissance of Brewer spruce stands be made to determine whether control measures are warranted to protect this rare tree.

A simplified method for estimating the extent of dwarf mistletoe-caused damage in immature lodgepole pine stands has been developed at the Rocky Mountain Station. By merely determining the percentage of trees infected in a stand, it is possible to estimate the length of time that dwarf mistletoe has been present, and from this, estimate the volume reduction due to growth loss and mortality. This information will help forest managers decide when infected stands should be harvested and whether mistletoe control is warranted.

Investigations of possible biological control agents for dwarf mistletoes continue in the West. Cytospora abietis, a fungus parasite that occasionally causes a canker of red fir and white fir, is commonly associated with dwarf mistletoe infected branches. The fungus was found on 30 to 40 percent of the dwarf mistletoe infections and appears to suppress growth and exert considerable control of dwarf mistletoe in some areas.

Three other fungus parasites, Wallrothiella arceuthobii, Septogleum gillii, and Colletotrichum gleosporioides, have been reported to occur commonly on dwarf mistletoes. However, their function as biologic control agents is controversial. A study by the Intermountain Station indicates that infectivity and virulence do not appear to limit the effectiveness of these fungi as biologic control agents. But, mode of action, probably the most crucial attribute of a biologic agent, is definitely a limiting factor for all three. These fungi should become more significant to the control effort as natural regulators of epiphytotics once the dwarf mistletoes are reduced to tolerable intensities by other measures such as silvicultural control.

The removal of all spruce from infected areas has been recommended for control of dwarf mistletoe in black spruce. A Lake States study evaluating the success of this method two and four years after treatment revealed that many infected seedlings were missed and that complete removal of reproduction by cutting alone is not feasible. For best results it is recommended that clear cutting be followed by a prescribed burn to insure complete elimination of infested seedlings.

6. Discoloration and decay. Many recent studies have pointed out that successions of microorganisms are involved in the discoloration and decay processes. From such studies has emerged the hypothesis that decay in living trees is only the final stage in a long sequence of events and that most heartrotting fungi can decay wood only after it has been altered in some way. This hypothesis has been strengthened, for under controlled conditions three heartrot fungi decayed only those sugar maple tissues previously decayed or in an advanced stage of discoloration. In contrast, a saprotter decayed clear wood as well as wood previously discolored or decayed.

Basic studies of the physiology of decay organisms in Central hardwoods continued at Delaware, Ohio. Oxygen and carbon dioxide concentrations were measured in red oaks and marked quanitative differences were found between concentrations in tree trunks and in the atmosphere. In laboratory tests, dry weight production of four wood-decaying organisms was measured in liquid cultures under various oxygen and carbon dioxide concentrations. The response varied among the organisms but, in general, dry weight production decreased with a decrease in oxygen concentration below atmospheric levels and with an increase in carbon dioxide concentration from zero. Thus, these gases may influence the activity of wood-decaying organisms in living trees and perhaps play a role in the inactivation of decay columns.

Investigations on the effect of temperature on growth of heartrot decay fungi showed that growth of all four organisms studied was best at constant temperatures between 80 and 85° F. Small fluctuations in temperature increased the growth of these organisms while large fluctuations decreased it.

Investigations to characterize and purify the cellulase enzyme system in a heart rot decay organism, Stereum gausapatum, are underway. The system exhibited the same general characteristics regardless of the type of cellulose substrate. However, the ability of the organism to produce the system varied with cultural conditions. The enzyme system has been partially purified and separated into two parts: a cellobiase fraction and a cellulase fraction.

Decay in hardwood trees is often inhibited or halted after wounds heal. Research at the Southern Station reveals the extent that heart rot is affected by wound closure. After 5 years, infection occurred on all wounds that were kept open, but on only half of those which were allowed to heal. Resulting decay from these extended only 10% as far as from open wounds.

In studies of beaver-damaged bottomland hardwoods in Mississippi the extent of decay associated with partial girdles was measured. Rots two inches deep were observed after five years in sugarberry, six years in ash, and eight years in sweetgum. A 10-year salvage cycle is recommended and should reduce losses considerably.

Brown rots were responsible for nearly half of the total decay cull in merchantable ponderosa pine in the Black Hills of South Dakota. Veluticeps berkeleyi was the most damaging of the brown rot fungi. This is the first report of V. berkeleyi causing decay in living trees: previously it was reported causing a brown cubical rot in the sapwood of killed timber. It enters trees through old branch stubs and fire scars and is capable of rendering entire trees unmerchantable in the older age classes. Descriptions of its cultural characteristics and the associated rot were published to aid in future identifications of this fungus.

In a study of decay in oak stands in Kentucky, decay losses averaged less than 1 percent in stands under 90 years of age, while in stands over 90 years of age decay losses averaged over 5 percent of the gross merchantable volume. Scarlet oak had the greatest amount of decay followed by chestnut, black, northern red, and white oak in that order. Twenty-six percent of the 2,161 trees in the study contained measurable amounts of decay. The percentage of all oak species with decay increased progressively with increasing diameter from less than 7 percent in the smallest diameter class to 100 percent in trees 19.6 inches in diameter and larger.

A long-term study of decay and discoloration associated with skidding injuries in Lake States yellow birch and sugar maple shows that value losses are very low 10 years after injury. Certain wound characteristics are closely correlated with value loss and can be used to identify trees sustaining nearly all loss. Since nearly all northern hardwood stands in this region are managed under a selection system with a 10-year cutting cycle, high-risk trees injured during the preceding cut could be removed during each successive cut and losses sharply reduced.

A study of deterioration in beetle-killed Douglas-firs in western Oregon and Washington showed that losses advanced from 3 to 79 percent of the board-foot volume during the period 1 to 11 years following death. Rate of deterioration and felling breakage are related to tree age and size. The red belt fungus, Fomes pinicola caused most of the losses. Methods for determining time of tree death and the volume deteriorated were determined, along with guidelines for salvaging maximum values from the dead trees.

Basic studies of spore germination and penetration by heartrotting fungi being made under a Forest Service research grant at Pennsylvania State University indicate that the common host specificity of heartrotting fungi is not conditioned by factors controlling spore germination. Where spores of one fungus would germinate, all would germinate and vice-versa. However, difficulty was experienced in germinating spores of several fungi under any conditions. Internal dormancy may be involved as may the presence or absence of associated yeasts and bacteria. Studies of this are underway. Several compounds have been isolated from the bases of eastern white pine branch stubs and tested for their effect on spore germination. Some are inhibitory, but their effect in nature has not been determined. These may also effect penetration.

D. Foliage diseases

1. Conifers. Elytroderma needle cast of ponderosa pine intermittently causes severe local damage in eastern Oregon and Washington. Recently completed studies show that growth rates are reduced in approximate proportion to crown damage. Uncrowded saplings and poles with healthy leaders can recover from rather severe infections if not attacked by other parasites while weakened. Moderately infected trees are more susceptible to root disease and insect attacks and heavily infected trees are often killed directly by defoliation. Recommendations developed for managing infected ponderosa pine stands will alleviate losses from this disease.

As part of a continuing study to determine the needle cast fungi present and their potential importance in Rocky Mountain conifers, a collection from Engelmann spruce was examined. The fungus was found to be Bifusella crepidiformis, a species previously not known from the Western United States. Previous studies of the fungus on eastern species suggest that it is a weak parasite; hence, it is not expected to be a serious needle cast in the West.

Injury of Arizona ponderosa pine afflicted continuously with needle cast from 1955 to 1967 was associated primarily with Lophodermella cerina. A portion of the damage was attributed to climatic injury not associated with fungal invasion. A still smaller amount of injury was attributable to other needle cast fungi. Studies of a small epiphytotic of L. cerina in Colorado confirm the ability of this fungus to cause continuing severe foliar damage over at least a 5-year period.

Grafted scions susceptible to infection by Davisomycella medusa showed that the fungus is capable of incubation in pine foliage for a period of at least 2 years prior to development of obvious symptoms and fruiting bodies. There is no evidence that the fungus is capable of systemic development, so that incubation probably occurs within the foliage. Control measures applied in ignorance of such prolonged incubation periods would likely be ineffective.

Cooperative studies by the Rocky Mountain Station and Colorado State University on an unexplained needle disease in ponderosa pine in the Denver, Colorado area, have established a direct relationship between high sodium content of the needles and severity of symptom expression. It appears that the sodium comes in some instances from irrigation and natural seepage waters rather than from street salt applications. Results of chloride analyses and studies on experimental reproduction of symptoms are pending.

A comprehensive review of the North American literature on Dothistroma needle blight shows the disease to be present in 22 states in the United States and in three provinces of Canada. The pathogen has been found on 20 pine species and hybrids in North America; hosts include 2-, 3-, and 5-needled pines. In the central United States, exotic pines have been severely damaged. Damage in plantations and natural stands of lodgepole and ponderosa pine in Washington, Oregon, Montana, and Idaho has varied from light to heavy.

Epidemiology and control of Dothiostroma needle blight on Austrian pine and ponderosa pine were studied in eastern Nebraska. Good control was obtained with Bordeaux mixture and other copper fungicides. Two properly timed applications of Bordeaux mixture provided excellent control. In California, studies of D. pini on Monterey pine indicate that climate may hold the disease on this species in check for most of the state.

2. Hardwoods. Russian-olive has been planted in the Great Plains for more than 60 years. It has been widely used in shelterbelts because it is drought hardy and salt tolerant. Its early performance was not marked by any serious disease. Now, however, it is in widespread decline in the Plains. A fungus has consistently been isolated from affected trees. Inoculations of Russian-olive in the greenhouse and field have established pathogenicity and the fungus has been identified as Botryodiplodia theobramae.

In the South, inoculation tests, plus morphological similarities, established that the fungus Melampsora medusae is the cause of a leaf rust of eastern cottonwood.

Dieback-decline diseases are usually initiated by an adverse environmental factor operating directly or indirectly on the host tree. Such factors as drought, late spring frosts, insect defoliation, etc., often predispose trees to invasion by organisms of secondary action. At the Northeastern

Station, studies of the effects of defoliation on root food reserves in sugar maple showed that both quantity and quality of food reserves are affected by defoliation. Related preliminary tests revealed that growth in culture of Armillaria mellea, a root rotting fungus of secondary action, was enhanced by defoliation-induced changes in root sugar quality.

E. Systemic diseases

Investigations of host-parasite physiology in oak wilt at the Northeastern Station indicate distribution of the causal fungus, Ceratocystis fagacearum, during the development of the disease and the relationship of this distribution to leaf symptom expression and resistance to water movement in the xylem. In general, the pathogen is distributed throughout the stem of infected oak seedlings prior to leaf symptom expression. Retardation of water movement occurs just before or at the time wilt symptoms appear in the leaves.

A better understanding of how the oak wilt fungus kills trees has important practical and theoretical implications. In studies to this end, a phytotoxic substance, produced by the oak wilt fungus in culture, has been partially isolated. It will cause wilting and necrosis in oak leaves. Suitable media and the time requirements for production of this substance as well as certain of its solubility and chromatographic properties have been determined.

Two problems in oak wilt research technique have been solved. As a preliminary step to assessing the activity of enzymes during oak wilt development, a procedure has been perfected that permits oak xylem to be homogenized without destroying enzyme activity. For another series of studies, a convenient and rapid inoculation method for small tree seedlings has been developed that allows an inoculum suspension to be drawn into the vascular system of the plant exclusive of air.

Pathologists at the Southern Station's Stoneville, Mississippi laboratory have reported Cephalosporium wilt of elm for the first time in the Midsouth.

P.L. 480 sponsored research in India revealed widespread losses, as high as 80 percent in certain areas, by Tricosporium wilt of Casuarina.

F. Biology and taxonomy of forest fungi

At the Forest Disease Laboratory, Laurel, Maryland, basic studies clarifying the taxonomy and cultural characteristics of several important forest fungi were completed and the role of light and temperature in fruiting by Panus fragilis was determined. Mature sporophores developed in 22-31 days at the longest day cycle tested, 12 hours at 792 foot candles, with daily temperature fluctuations of 22° C. for 12 hours and 8° C. for 12 hours.

During the past year, 350 fungal cultures were received for identification and 177 identified, 228 named cultures were shipped to scientists on request and 132 fungal specimens were identified. Sixty-four specimens were deposited in other herbaria and 246 were added to the herbarium at the Laurel laboratory.

Heterothallism was demonstrated for the first time in the genus Pythium at the Southeastern Station. A new species, Pythium sylvaticum, was isolated from nursery, forest, and agricultural soils as a non-oospore producing phycomycete. Mating of male and female strains produced the oospores needed for identification. Discovery of heterothallism in the genus provides a means of identifying forms previously considered unidentifiable. A second heterothallic Pythium sp., considered new, and named Pythium heterothallicum was isolated from soil in Florida, Tennessee, North Carolina, Utah, and Alberta, Canada. Although associated with a wide variety of plants, its pathogenic potential has not yet been determined.

G. Miscellaneous disease studies

Annual disease loss in Pacific Northwest forests was estimated at 3.1 billion bd. ft. or 403 million cu. ft. in a study of the Pacific Northwest Station. Of this, 162 million cu. ft. is potential growth prevented by disease, 129 million is mortality, and 112 million cull. Dwarf mistletoes (148 million cu. ft.), root rots (115 million), and heart rots (110 million) are principal causes of disease loss. Priorities for research on disease problems can now be established more reliably.

In a study by the Pacific Southwest Station on Federal recreation sites in California, one of every 21 tree failures causes an injury or fatality and one of every two to three failures results in an accident. Property losses, exclusive of clean-up costs, were estimated to run in excess of $25,000 annually not including personal injury suits and awards. For effective control of hazardous defect in trees, the recreation land manager needs information, techniques, and directives which will enable him to attain a defined level of control based on an acceptable level of accidents, an acceptable level of control expenditures, or an acceptable hazard rating criterion. A procedure was outlined for assigning priorities to various classes of defect on the basis of cost-effectiveness. The guidelines and work sheet allow for planning an effective local program in the case of budgetary restrictions, or for estimating local budget requirements to meet specified performance goals.

Preliminary results of a trial by the Northeastern Station to evaluate infrared aerial photography as a tool to detect and assess beech bark disease were encouraging. Thus far, there is no evidence that infrared will reveal more than true color films, but the foreign colors enhanced the observer's ability to pick out small differences not apparent on true color films.

Two simple and inexpensive techniques developed by Pacific Northwest researchers greatly speed routine laboratory culture work with microorganisms. One utilizes a modified phonograph turntable to spread soil dilutions on agar plates uniformly and easily. The other uses sterile wooden toothpicks for transferring inoculum eliminating several intermediate steps from the usual method.

RPA 214 - PROTECTION OF PLANTS FROM AIR POLLUTION

In North Carolina, field screening for candidate eastern white pines to be tested as bioindicators of air pollutants was continued as planned. Seedlings have now been exposed for 1 year in each of three exposure areas. Numbers of seedlings injured during only one season in a single area and resistant during all other seasons regardless of the area are as follows:

(1)	Sulfur dioxide exposure	- winter -	42
(2)	Sulfur dioxide exposure	- summer -	1
(3)	Fluoride exposure	- winter -	3
(4)	Fluoride exposure	- summer -	116
(5)	Oxidant exposure	- winter -	3
(6)	Oxidant exposure	- summer -	7

Thirty-three seedlings were resistant to atmospheric phytotoxicants during all six of the above exposures. Treatment with a balanced fertilizer was found to induce resistance in clones of eastern white pine normally sensitive to air pollution injury. Biochemical studies showed that carbohydrate levels in white pine foliage could be correlated with ozone sensitivity and might be a more useful indication of the degree of sensitivity than needle length, the criterion currently used.

An air pollution exposure chamber was developed at the Southeastern Station and is unique in that (1) construction costs are low, (2) good control of temperature and humidity can be obtained, and (3) sunlight is used for illumination. Good control of either ozone or sulfur dioxide concentrations can be obtained. In tests using the new chamber, eastern white pine was injured at only 0.25 p.p.m. SO_2 in one hour, a new low injury threshold for this species.

Investigations are continuing on the effects of parentage, site, and juvenile characteristics upon eastern white pine nursery seedlings which become chlorotic dwarf, an air pollution - induced disorder, when established in Ohio plantations. Statistical correlations indicate a relationship between specific seedling characters and the occurrence of affected plantation trees. This finding will allow early detection of latent chlorotic dwarfs in nursery beds and elimination of these seedlings during nursery grading practices.

Continuous air pollution monitoring in August and September at 5,000 to 6,100 feet elevation in the San Bernardino Mountains of California showed an average daily peak of ozone of 0.23 p.p.m. at the lower elevation and 0.17 p.p.m. at the higher station. Short sample periods at other mountain locations revealed a typical late afternoon elevation of air pollution. In the San Bernardino Mountains and adjacent ranges, severe photochemical air pollution injury to several species of conifers is evident. In the Lake Arrowhead area alone approximately 25,000 acres of trees on high-value recreation land are affected and being killed.

RPA 801 - HOUSING RESEARCH

Studies of spore germination at the Southern Station show that the rate at which fresh pine lumber dries alters its susceptibility to staining fungi, but does not affect the germination of spores of Lenzites saepiaria, an important wood-decaying fungus. Drying alone does not prevent decay by this fungus; and effective preservative must also be used to protect the wood in service.

Water spray storage of pine logs in the South increases resistance of the wood to decay and stain fungi, increases penetrability of the wood to liquids, but has an adverse effect on toughness. The increased permeability favors better penetration of wood preservatives, which, with the enhanced resistance to decay makes for longer life of the wood in service.

It was determined that southern yellow pine has a low phosphorous content. Addition of sodium phosphate to such wood materials under laboratory conditions enhanced decay by Lenzites saepiaria. This fungus exhibits an unusually high specific activity of acid phosphatase which suggests that when phosphorous is limited this enzyme accelerates the turnover of intracellular phosphate. This phosphate recycling mechanism may be one of several unique physiological attributes of L. saepiaria which enables it to utilize wood.

Basic studies of the biochemistry of wood deterioration by North Carolina State University continued under a Forest Service grant. Evidence obtained indicates that lignin is a polymer of finite rather than infinite size and that it differs in molecular size according to its location in the wood cell walls.

In a P.L. 480 project in India, evaluations of natural decay resistance in the heartwood of 52 species of Indian timber continued. Sal and teak, the two most resistant timber species owe most of their resistance to water or organic soluble toxic materials as in the case with most other such timbers. Resistance was generally somewhat lower in field tests than in the laboratory and is probably due to leaching and/or weathering of the toxic materials.

Publications - USDA and Cooperative Program

RPA 202 - CONTROL OF DISEASES OF FOREST TREES

Seed and seedling diseases

Campbell, W. A., and F. F. Hendrix, Jr. 1967. Pythium and Phytophthora species in forest soils in the southeastern United States. Plant Dis. Reptr. 51: 929-932.

Campbell, W. A., and F. F. Hendrix, Jr. 1967. A new heterothallic Pythium from southern United States. Mycologia 59: 274-278.

Filer, T. H., Jr. 1967. Damping-off of sweetgum by Pythium sylvaticum. Phytopathology 57: 1284.

Papa, K. E., W. A. Campbell, and F. F. Hendrix, Jr. 1967. Sexuality in Pythium sylvaticum: heterothallism. Mycologia 59: 589-595.

Peterson, Glenn W. 1967. Control of Cylindrosporium leaf spot disease of Rhus trilobata and Shepherdia argentea seedlings. Plant Dis. Reptr. 51: 700-701.

Smith, Richard S., Jr. 1967. Decline of Fusarium oxysporum in the roots of Pinus lambertiana seedlings transplanted into forest soils. Phytopathology 57: 1265.

Smith, Richard S., Jr., and Stanley L. Krugman. 1967. Control of the charcoal root disease of white fir by fall soil fumigation. Plant Dis. Reptr. 51: 671-674.

Verrall, A. F. 1967. Brown spot needle blight, Scirrhia acicola. Pp. 237-238. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Root diseases

Campbell, W. A. 1967. Phytopthora spp. Pp. 57-60. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Harvey, A. E. 1967. Effect of phytoactin treatment on mycorrhizae-root consociations in western white pine. Plant Dis. Reptr. 51: 1012-1013.

Hodges, C. S., and E. Jorgensen. 1967. Fomes annosus root rot, Fomes annosus. Pp. 48-52. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Juo, Pei-Show and G. Stotsky. 1967. Interference by nitrate and nitrite in the determination of carboyhdrates by anthrone. Analytical Biochemistry 21: 150-151.

Li, C. Y., K. C. Lu, J. M. Trappe, and W. B. Bollen. 1967. Effect of pH and temperature on growth of Poria weirii in vitro. U. S. Forest Serv. Res. Note PNW-66, 6 pp.

Marx, D. H. 1967. Ectotrophic mycorrhizae as biological deterrents to pathogenic root infections by Phytophthora cinnamomi. XIV. IUFRO-Congress, Section 24, pp. 172-181. Munich.

Marx, D. H., and C. B. Davey. 1967. Ectotrophic mycorrhizae as deterrents to pathogenic root infections. Nature 213: 1139.

Raski, D. J. and J. W. Riffle. 1967. Two new species and further notes on Criconemoides Taylor, 1936 (Criconemoidae: Nematoda). Proc. Helminthol. Soc. of Washington. 34: 212-219.

Riffle, Jerry W. 1967. Effect of an Aphelenchoides species on the growth of a mycorrhizal and a pseudomycorrhizal fungus. Phytopathology 57: 541-544.

Riffle, Jerry W. 1968. Plant-parasitic nematodes in marginal ponderosa pine stands in central New Mexico. Plant Dis. Reptr. 52: 52-55.

Ross, E. W. 1967. Practical control of Fomes annosus in southern pines. XIV. IUFRO-Congress, Section 24, pp. 321-324. Munich.

Ruehle, John L. 1967. Distribution of plant-parasitic nematodes associated with forest trees of the world. U. S. Forest Service, Southeastern Forest Experiment Station, 156 pp.

Smith, Richard S., Jr. 1967. Verticicladiella root disease of pines. Phytopathology 57: 935-938.

Smith, Richard S., Jr. 1967. Decline of Fusarium oxysporum in the roots of Pinus lambertiana seedlings transplanted into forest soils. Phytopathology 57: 1265.

Smith, Richard S., Jr., and Stanley L. Krugman. 1967. Control of the charcoal root disease of white fir by fall soil fumigation. Plant Dis. Reptr. 51: 671-674.

Toole, E. R. 1967. Root rot of southern hardwood trees caused by Corticium galactinum. Plant Dis. Reptr. 51: 500-501.

Trappe, James M. 1967. Pure culture synthesis of Douglas-fir mycorrhizae with species of Hebeloma, Suillus, Rhizopogon, and Astraeus. Forest Sci. 13: 121-130.

Trappe, J. M. 1967. Principles of classifying ectotrophic mycorrhizae for identification of fungal symbionts. XIV. IUFRO-Congress, Section 24, pp. 46-59. Munich.

Wright, E. 1967. Texas or cotton root rot, Phymatotrichum omnivorum. Pp. 235-236. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Stem diseases

Anderson, Gerald W., and Ralph L. Anderson. 1968. Relationship between density of quaking aspen and incidence of hypoxylon canker. Forest Sci. 14: 107-112.

Anderson, Neil A., David W. French, and Ralph L. Anderson. 1967. The stalactiform rust on jack pine. J. Forest. 65: 398-402.

Anderson, R. L. 1967. Hypoxylon canker of aspen, Hypoxylon pruinatum. Pp. 192-194. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Benedict, W. V. 1967. White pine blister rust, Cronartium ribicola. Pp. 184-188. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Bingham, R. T. 1967. Economical and reliable estimates of general combining ability for blister rust resistance obtained with mixed-pollen crosses. U. S. Forest Serv. Res. Note INT-60, 4 pp.

Bingham, R. T. 1967. International aspects of blister rust resistance in white pines. XIV. IUFRO-Congress, Section 24, pp. 832-841. Munich.

Brown, R. A., and S. J. Rowan. 1967. Sodium arsenite: a possible eradicant of fusiform rust infections. U. S. Forest Serv. Res. Note SE-75, 3 pp.

Childs, T. W. 1968. Comandra rust damage to ponderosa pine in Oregon and Washington. U. S. Forest Serv., Pac. NW. Forest & Range Exp. Sta. Misc. Publ., 8 pp.

Childs, T. W., and J. W. Edgren. 1967. Dwarfmistletoe effects on ponderosa pine growth and trunk form. Forest Sci. 13:167-174.

Cordell, C. E., D. D. Skilling, and J. W. Benzie. 1968. Susceptibility of three pine species to Scleroderris lagerbergii in Upper Michigan. Plant Dis. Reptr. 52: 37-39.

Davidson, A. G., and M. E. Fowler. 1967. Scab and black canker of willow Pollaccia saliciperda and Physalospora miyabeana. Pp. 201-203. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Dochinger, Leon S. 1967. Occurrence of poplar cankers caused by Fusarium solani in Iowa. Plant Dis. Reptr. 51: 900-903.

Filer, T. H., Jr. 1967. Pathogenicity of Cytospora, Phomopsis, and Hypomyces on Populus deltoides. Phytopathology 57: 978-980.

French, D. W., M. P. Meyer, and R. L. Anderson. 1968. Control of dwarf-mistletoe in black spruce. J. Forest 66: 359-360.

Gilbertson, R. L., Frances F. Lombard, and T. E. Hinds. 1968. Veluticeps berkeleyi and its decay of pine in North America. Mycologia 60: 29-40.

Hansbrough, J. R. 1967. Bacterial canker of poplar in North America. XIV. IUFRO-Congress, Section 24, p. 427. Munich.

Harvey, Alan E. 1967. Tissue culture of Pinus monticola on a chemically defined medium. Can. J. Bot. 45: 1783-1787. 1967.

Harvey, George M. 1967. Growth rate and survival probability of blister rust cankers on sugar pine branches. U. S. Forest Serv. Res. Note PNW-54, 6 pp.

Hawksworth, Frank G. 1967. Distribution of ponderosa pine dwarf mistletoe on the South Rim of Grand Canyon, Arizona. Plant Dis. Reptr. 51: 1049-1051.

Hawksworth, F. G. 1967. Dwarf mistletoes, Arceuthobium spp. Pp. 31-35 In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 249 pp.

Hawksworth, F. G. 1967. Mistletoes, Phoradendron spp. Pp. 232-234. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Hawksworth, Frank G. 1968. Lodgepole pine dwarf mistletoe on ponderosa pine. Plant Dis. Reptr. 52: 125-126.

Hawksworth, Frank G., Delbert Wiens, and Donald P. Graham, 1967. Dwarf-mistletoe on Brewer spruce in Oregon. Northwest Sci. 41: 42-44.

Hinds, T. E. and R. W. Davidson. 1967. A new species of Ceratocystis on aspen. Mycologia 59: 1102-1106.

Jensen, Keith F. 1967. Measuring oxygen and carbon dioxide in red oak trees. U. S. Forest Serv. Res. Note NE-74, 4pp., illus.

Jensen, Keith F. 1967. Oxygen and carbon dioxide affect the growth of wood-decaying fungi. Forest Sci. 13: 384-389.

Koenigs, J. W. 1968. Culturing the white pine blister rust fungus in callus of western white pine. Phytopathology 58: 46-48.

Krebill, R. G. 1968. Histology of canker rusts in pines. Phytopathology 58: 155-164.

Laycock, W. A., and R. G. Krebill. 1967. Comandra, grazing, and comandra blister rust. U. S. Forest Serv. Res. Pap. INT-36, 9 pp.

Laycock, William A., and R. G. Krebill. 1967. Comandra is not an invader on most western ranges. U. S. Forest Serv., Region 4, Range Impr. Notes 12: 1-5.

Leaphart, Charles D., and Ed F. Wicker. 1967, The ineffectiveness of cycloheximide and phytoactin as chemical controls of the blister rust disease. Plant Dis. Reptr. 52: 6-10.

Lightle, Paul C., Stewart R. Andrews, and W. E. Mouser. 1967. Recleaning the dwarf mistletoe control area on the Mescalero Apache Indian Reservation, New Mexico. J. Forest. 65: 816-817.

Mielke, J. L., and R. S. Peterson. 1967. Albino Peridermium harknessii in ponderosa pine. Plant Dis. Reptr. 51: 306-309.

Ohman, John H. 1968. Decay and discoloration of sugar maple. U. S. Forest Serv., Forest Pest Leafl. 110, 6pp. illus.

Patton, R. F. 1967. Factors in white pine blister rust resistance. XIV. IUFRO-Congress, Section 24, pp. 876-890. Munich.

Peterson, R. S. 1967. Limb rust, Peridermium filamentosum and P. stalactiforme. Pp. 228-231. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Peterson, Roger S. 1967. Cypress rusts in California and Baja, California. Madroño 19: 47-54.

Peterson, Roger S. 1967. The Peridermium species on pine stems. Torrey Bot. Club Bull. 94: 511-542.

Peterson, Roger S. 1967. Studies of juniper rusts in the West. Madroño 19: 79-91.

Peterson, Roger S. 1968. Rust fungi on Araucariaceae. Mycopathologia et Mycologia Applicata 34: 17-26.

Peterson, Roger S. 1968. Limb rust of pine: The causal fungi. Phytopathology 58: 309-315.

Peterson, Roger S., and Eunice A. Cronin. 1967. Nonrosaceous host of Phragmidium (Uredinales). Plant Dis. Reptr. 51: 766-767.

Peterson, R. S., and R. G. Krebill. 1967. Comandra blister rust, Cronartium comandrae. Pp. 39-41. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Peterson, R. S., and R. Salinas Quinard. 1967. Cronartium conigenum: Distribucion y efectos en los pinos. Instituto Nacional de Investigaciones forestales, Mexico. Boletin Tecnico 19, 11 pp., illus.

Phelps, William R., and Ray Weber. 1967. Translocation and persistence of cycloheximide and phytoactin in eastern white pine. Forest Sci. 13: 90-94.

Quick, Clarence R. 1967. Screening conventional fungicides . . . control of blister rust on sugar pine in California. U. S. Forest Serv. Res. Note PSW-149. 7 pp., illus.

Quick, Clarence R. 1967. Chemical control of blister rust on sugar pine . . . two fungicides show promise in California tests. U. S. Forest Serv. Res. Note PSW-147. 8 pp., illus.

Scharpf, Robert F., and J. R. Parmeter, Jr. 1967. Spread of dwarfmistletoe into Jeffrey pine plantation . . . trees infected after 22 years. U. S. Forest Serv. Res. Note PSW-141. 6 pp., illus.

Schreiber, Lawrence R., and Leon S. Dochinger. 1967. Fusarium canker on paper mulberry (Broussonetia papyrifera). Plant Dis. Reptr. 51: 531-532.

Shigo, Alex L. 1967. The early stages of discoloration and decay in living hardwoods in northeastern United States: A consideration of wound-initiated discoloration and heartwood. XIV. IUFRO-Congress, Section 41, pp. 117-133. Munich.

Shigo, Alex L. 1967. Successions of organisms in discoloration and decay of wood. Internatl. Rev. Forestry Res. Vol. 2: 237-299.

Shigo, A. L., and G. L. Stone. Beech bark disease. Nectria coccinea var. faginata. Pp. 195-198. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Toole, E. R. 1967. Rates of wood decay behind open and closed wounds. Plant Dis. Reptr. 51: 600.

Toole, E. R., and R. M. Krinard. 1967. Decay in beaver-damaged southern hardwoods. Forest Sci. 13: 316-318.

Van Arsdel, E. P. 1967. The nocturnal diffusion and transport of spores. Phytopathology 57: 1221-1229.

Verrall, A. F. 1967. Southern fusiform rust, Cronartium fusiforme. Pp. 221-223. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Walkinshaw, Charles H., James M. Hyde, and Janice Van Zandt. 1967. Fine structure of quiescent and germinating aeciospores of Cronartium fusiforme. Jour. Bacteriology 94: 245-254.

Wicker, Ed F. 1967. Seed destiny as a klendusic factor of infection and its impact upon propagation of Arceuthobium spp. Phytopathology 57: 1164-1168.

Wicker, Ed F. 1967. Appraisal of biological control of Arceuthobium campylopodum f. campylopodum by Colletotrichum gloeosporioides. Plant Dis. Reptr. 51: 311-313.

Wicker, Ed F., and C. Gardner Shaw. 1967. Target area as a klendusic factor in dwarf mistletoe infections. Phytopathology 57: 1161-1163.

Wicker, Ed F., and C. Gardner Shaw. 1968. Fungal parasistes of dwarf mistletoes. Mycologia 60: 372-383.

Wicker, Ed F., and J. M. Wells. 1968. Overwintering of Tuberculina maxima Rostr. on white pine blister rust cankers. Phytopathology 58: 391.

Wiens, Delbert. 1968. Chromosomal and flowering characteristics in dwarf mistletoes (Arceuthobium). Amer. J. Bot. 55: 325-334.

Wright, K. H., and G. M. Harvey. 1967.
The deterioration of beetle-killed Douglas-fir in western Oregon and Washington. U. S. Forest Serv. Res. Pap. PNW 50, 20 pp.

Yu, Peter H., Chi-Chang Chen, and Lung-Chi Wu. 1967. Studies on growth and perithecia formation in the genus Nectria. Botanical Bulletin of Academia Sinica 8: 117-129.

Foliage diseases

Andrews, S. R. 1967. Adelopus needle cast, Adelopus (Phaeocryptopus) gaumanni. Pp. 171-172. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Buchanan, T. S. 1967. Diplodia twig blight of pine, Diplodia pinea. Pp. 189-191. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico, Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Chen, Chi-Chang. 1966. Some observations on anthracnose of China fir. Plant Plant Protection Bulletin 8: 127-132.

Chen, Chi-Chang. 1967. Survey of epidemic diseases of forest trees in Taiwan. Botanical Bulletin of Academia Sinica 8: 130-148.

Chen, Jiann-Shin, Wen-Luan Hsiao, Yuan-Shen Huang, and Chi-Chang Chen. 1966. Physiological studies on Macrophoma chionanthi. Plant Protection Bulletin 8: 117-126.

Childs, T. W. 1967. Elytroderma needle cast, Elytroderma deformans. Pp. 45-47. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Houston, David R. 1967. The dieback and decline of northeastern hardwoods. Trees Magazine 28: 12-14.

Kessler, K. J., Jr. 1967. Dieback not a cause of mortality or reduction of growth or quality in Lake States northern hardwoods. J. Forest 65: 892-893.

Matthews, F. R. 1967. Southern cone rust, Cronartium strobilinum. Pp. 224-227. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Moriondo, F. and B. M. Naldini. 1967. Host relationship of Melampsora **pinitorqua** Rostr. XIV. IUFRO Congress, Section 24, pp. 373-374. Munich.

Parker, J. 1968. Drought resistance of roots of white ash, sugar maple, and red oak. U. S. Forest Serv. Res. Pap. NE-95.

Peterson, Glenn W. 1967. Dothistroma needle blight of Austrian and ponderosa pines: epidemiology and control. Phytopathology 57: 437-441.

Peterson, Glenn W. 1967. Dothistroma needle blight of pines in North America. XIV. IUFRO-Congress, Section 24, pp. 269-278. Munich.

Peterson, G. W. 1967. Cedar blight, Phomopsis juniperovora. Pp. 55-56. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Staley, John M. and Frank G. Hawksworth. 1967. Bifusella crepidiformis on Engelmann spruce. Plant Dis. Reptr. 51: 791-792.

Toole, E. R. 1967. Melampsora medusae causes cottonwood rust in lower Mississippi Valley. Phytopathology 57: 1361-1362.

Wagener, Willis W. 1967. Red band needle blight of pines . . . a tentative appraisal for California. U. S. Forest Serv. Res. Note PSW-153. 6 pp.

Systemic diseases

Filer, T. H., Jr., F. I. McCracken, and E. R. Toole. 1968. Cephalosporium wilt of elm in lower Mississippi Valley. Plant Dis. Reptr. 52: 170-171.

Seliskar, C. E. 1967. Oak wilt, Ceratocystis fagacearum. Pp. 173-176. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Biology and Taxonomy of Forest Fungi

McKay, Hazel H. 1967. Cultural studies of Polyporus meliae and two similar species. Mycologia 59: 1050-1058.

Miller, Orson K., Jr. 1967. Notes on western fungi. I. Mycologia 59: 504-512.

Miller, Orson K., Jr. 1967. The role of light in the fruiting of Panus fragilis. Canad. Jour. Botan. 45:1939-1943.

Miller, Orson K., Jr. 1968. A revision of the genus Xeromphalina. Mycologia 60: 156-188.

Miscellaneous disease studies

Berry, Frederick H. 1966. Diseases of black walnut. The Nutshell 14: 10-13.

Berry, Frederick H. 1967. Sweetgum diseases. In: Univ. of Missouri Tree Serv. Conf. Proc. 1966: 22-25.

Childs, T. W., and K. R. Shea. 1967. Annual losses from disease in Pacific Northwest forests. U. S. Forest Serv., Pac. NW. Forest & Range Exp. Sta. Resource Bull. PNW-20, 19 pp.

Hansbrough, J. R. 1967. Introduction. Pp. 9-10. In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Canada Dept. of Forestry and Rural Development Pub. No. 1180, 248 pp.

Hansbrough, J. R. 1967. Directories of forest pathologists. XIV. IUFRO Congress, Section 24, p. 384. Munich.

Hansbrough, J. R. 1967. IUFRO Working Group on international cooperation in forest disease research: History, organization, objectives, and progress. XIV. IUFRO-Congress, Section 24, pp. 388-390. Munich.

Hepting, G. H. 1967. The INTREDIS register for literature retrieval in forest pathology. XIV. IUFRO-Congress, Section 24, pp. 385-387. Munich.

Hepting, George H. 1967. International tree disease register. Agric. Science Review 5: 33-34.

Hepting, George H. 1967. Measuring losses from forest diseases. XIV. IUFRO-Congress, Section 24, pp. 325-326. Munich.

Neal, J. L., Jr., K. C. Lu, W. B. Bollen, and J. M. Trappe, 1967. Two simple time-saving techniques for studies of soil micro-organisms. U. S. Forest Serv. Res. Note PNW-57, 3 pp.

Paine, Lee A. 1967. Effective tree hazard control on forested recreation sites . . . losses and protection costs evaluated. U. S. Forest Serv. Res. Note PSW 157, 8 pp.

Paine, Lee A. 1967. Tree hazard control on recreation sites . . . estimating local budgets. U. S. Forest Serv. Res. Note PSW-160, 5 pp.

Powers, H. R. 1968. A current appraisal of forest tree diseases in the South. Forest Farmer Manual 27: 44-45.

Riffle, Jerry W. and H. W. Springfield. 1968. Hydrogen peroxide increases germination and reduces microflora on seeds of several woody species. Forest Sci. 14: 96-100.

RPA 214 - PROTECTION OF PLANTS FROM AIR POLLUTION

Dochinger, Leon S. 1967. Chlorotic dwarf of white pine a problem of air pollution. Ohio Woodlands 5: 18-19.

Dochinger, Leon S. 1968. Chlorotic dwarf in eastern white pine. Northeast. Area Nurserymen's Conf. Proc. 1967: 1-5. Point Pleasant, W. Va.

Hansbrough, J. R. 1967. Air quality and forestry. Pp. 45-55. In: Agriculture and the Quality of Our Environment. A Symposium Presented at the 133rd Meeting of the American Association for the Advancement of Science, December 1966. AAAS Publication 85.

RPA 801 - HOUSING RESEARCH

Bakshi, B. K., Y. N. Puri, and S. Singh. 1967. Natural decay resistance of Indian timber. I. Introduction and method. II. Decay resistance of sal (Shorea robusta Gaertn.) and teak (Tectona grandis L. f.). Indian Forester 93: 305-328.

Brown, W., S. I. Falkehag, and E. B. Cowling. 1967. Molecular size distribution of lignin wood. Nature 214: 410-411.

Khan, S. N. 1967. Natural decay resistance of Indian timbers IV. Decay resistance of irul (Xylia xylocarpa Taub.) and laurel (Terminalia tomentosa Wight et Arn.) Indian Forester 93: 567-577.

Puri, Y. N. 1967. Natural decay resistance in Indian timbers III. Heartwood extractives of sal (Shorea robusta Gaertn.) and teak (Tectona grandis L. f.). Indian Forester 93: 447-454.

FOREST PRODUCTS AND ENGINEERING RESEARCH

FOREST PRODUCTS UTILIZATION RESEARCH

USDA and Cooperative Program

Location of Intramural Work	Scientist Man-Years F.Y. 1968			
	Research Problem Area			
	401	512	801	Total
California	1.0			1.0
Colorado	3.0			3.0
Georgia		3.0	6.0	9.0
Illinois	4.0			4.0
Louisiana	4.2			4.2
Minnesota	2.0			2.0
Montana	2.0			2.0
Ohio		2.6		2.6
Oregon		2.9		2.9
Pennsylvania		2.0		2.0
Puerto Rico	1.0			1.0
Washington	3.0			3.0
West Virginia	3.0			3.0
Wisconsin	74.9	4.3	26.6	105.8
Total	98.1	14.8	32.6	145.5

Intramural program is supplemented by extramural support representing (a) 0 SMY's at State Agricultural Experiment Stations, (b) 0 SMY's at other U. S. institutions, and (c) P. L. 480 funds in 3 countries representing 102,100 U. S. dollars equivalent.

Problems and Objectives

Adequate knowledge about timber qualities and characteristics is lacking. Hardwoods, small and low-value trees, and bark are inadequately utilized. There is excessive waste in harvesting and processing. Expanded structural applications are hindered by lack of efficient nondestructive evaluation systems. Frequent pollution of air and water results from disposal of effluents and waste materials. Overall, traditional markets for forest products are threatened seriously by technologically based, synthesized competing materials. Forest products industries have not advanced technically as rapidly as their competitors while facing a decline in the quality of available timber supplies, a trend that will continue.

Major objectives of the research are to develop and evaluate alternative ways for:

1. Developing more and better wood products to meet consumer needs.

2. Developing new and improved fiber and chemical products to increase utilization of low-quality trees, wastes, and residues and reduce pollution.

3. Developing engineering concepts and structural applications to attain increased efficiency, economy, and versatility in the use of wood and wood-base engineering materials.

4. Developing quality evaluation systems to enable accurate stumpage value appraisal and allocation of raw material to highest value use.

5. Providing improved and more serviceable low-cost housing for low-income families through new knowledge and more effective use of wood.

Progress - USDA and Cooperative Program

RPA 401 - NEW AND IMPROVED FOREST PRODUCTS

A. Wood Structure and Quality Relations

1. Predicting yield of clear cuttings. An ADP system for predicting yields of dimension parts from hard maple lumber that was discussed last year was measurably improved by reducing the computer analysis to an easy-to-use chart form. This development gives users of hardwood lumber an inexpensive basis for selecting the most economical grade of lumber to produce a specified order of dimension parts, calculate material costs, and determine whether maximum yield is obtained. The results also apply to other hardwood species graded by the standard rules. In addition to the savings in material costs

from the application of these results, they also should increase the use of low-grade lumber because now the user has a means to determine in advance the yield of these poorer grades.

2. Specific gravity variation. A study undertaken to determine whether the specific gravity of coast Douglas-fir wood is related to moisture availability and elevation showed that summer precipitation alone accounted for 31 percent of the specific gravity variation. Together with elevation, these two sources of environmental variations accounted for 53 percent of the variation in specific gravity. In addition to these influences, it was also concluded from this study that specific gravity decreases as summer precipitation and elevation increase and that percentage of latewood and tracheid wall thickness are the main anatomical determinants of specific gravity variation. This information should be useful to workers investigating the causes of variation in wood quality, and to a limited extent, the forest manager.

Another study involved determining variation in wood density and percent summerwood among nine loblolly pine seed sources. These properties tended to be associated with latitude, increasing from south to north, while dry weight volume was associated with longitude, decreasing from east to west. Coastal seed sources were higher in dry weight volume than inland sources. Performance of coastal North Central seed sources was above average in all properties examined. The southwest Georgia source ranked last in specific gravity, but because it ranked high in volume, it ranked second in wood dry weight. This information should be extremely useful to forest managers, tree breeders, and geneticists who wish to improve timber growing stock by selectively planting and breeding.

3. A new method for marking xylem growth. In the past this was accomplished by removing a series of cores at given intervals throughout the growing season. This causes extensive damage to the living tree and results in abnormal physiological responses that may possibly negate the effects of treatment.

A new method was developed to implant micro-needles through the bark and into the xylem. This method of marking uses the inherent ability of the cambial zone to respond to minute mechanical injury by producing a limited number of aberrant cells (about two) which do not interfere with normal growth patterns. These aberrant cells are then permanently retained as a mark within the annual ring. Removal of the sample containing the mark can be delayed until the end of the growing season or termination of the experiment, thereby minimizing damage to the tree during the period of study. This technique suggests a possible mechanism to evaluate the normal growth patterns of wood formation, or to study the effects of environment on differentiating xylem, without upsetting the physiological integrity of the tree. Researchers in Canada, Australia, New Zealand, and Poland are currently using this technique.

B. Solid Wood Processes and Products Development

1. Creosote testing. A simple, rapid, and reliable means of detecting significant petroleum oil adulteration of creosote by thin-layer chromatography was developed. It will reveal petroleum oil in amounts as little as 1 percent among the creosote constituents. This provides a long-needed practicable means of checking creosote suitability for marine use where petroleum lowers effectiveness against marine borers. A good start has also been made in developing an improved basis for characterizing the composition of various grades and qualities of creosote. Using a gas chromatograph, the constituents of commercial creosotes can be compared accurately, and the essential components identified. It will also be possible to determine the quality of creosote treatment rapidly and precisely by means of the "fingerprint" registered by the chromatograph.

2. Permeability of wood. An understanding of permeability is necessary for preservative, fire retardant, and stabilization treatments. The relative permeability of wood to gases and nonswelling liquids was investigated. The "superficial gas permeability" was shown to vary linearly with the reciprocal of absolute pressure. When extrapolated to infinite pressure, the gas permeability was shown to be identical to the permeability determined with nonswelling liquids. This proves that permeability is a characteristic of the wood and is independent of the permeating fluid.

The variation in "superficial gas permeability" with absolute pressure was used to estimate the average effective pore size in membrane-type filters and wood. The values obtained for filters fell between the average value determined from mercury intrusion and the maximum value from liquid displacement. The permeability of wood in these experiments was shown to vary approximately with the fourth power of the estimated pore size. There was substantial variation about the regression, however, indicating that both the number and size of pores were responsible for variations in permeability.

3. Accelerated research procedure for evaluating surfaces. Methods have been perfected for using reflected light and fluorescence microscopy in studying the properties of wood surfaces that affect performance of exterior coatings. The techniques permit direct examination of unaltered wood surfaces and varnish interfaces at magnifications up to about 600 diameters with dry objectives and 1,000 diameters with water-immersion objectives. With dry objectives, fragile wood surfaces can be examined periodically and returned to test in their natural state. The new techniques have saved considerable time and yielded much useful information in progressive observations of such occurrences as (1) microchecking and photodegradation of unvarnished and varnished wood surfaces during artificial weathering, and (2) the "wetting" of wood-varnish interfaces during studies of simulated cold weather condensation.

4. Improved drying of Rocky Mountain species. Over the years there has been a lack of acceptance and general prejudice against some central Rocky Mountain species because of the fact that they have been reaching the market improperly dried. These species constitute a large portion of our overall resource and their acceptance is essential. Research on the use of solar energy showed that a solar drier has substantial advantages over air drying in several areas where the species are located. Use of solar driers would reduce winter and spring drying problems in the area, and considerably improve the quality of the material produced. When reduction in drying defects is taken into account, the solar dryer is more economical than the present air drying methods used.

5. Super strength beams. Research has shown that beams stronger than the original wood can be constructed under conditions adaptable to mass production. In laboratory studies the dynamic modulus of elasticity of the mill-run, rotary-cut southern yellow pine veneer was determined. The rating process is adaptable to rapid production systems. The stiffest veneers were placed toward the outside of the laminated beams, and the limber veneers were located nearer the center. In the test beams, butt joints located at eight-foot intervals in the 1/6-inch laminae did not affect the modulus of elasticity. Other questions concerning effects of depth and joint location must still be investigated. Commercial production of such beams appears to be technical and economically feasible. Allowable stresses 1/3 higher than the present maximums for laminated beams appear possible. Such increased strength allowances will permit the use of laminated wood in constructions where its use is now limited because of higher than available strength requirements, or will permit a lesser number of beams than are presently required, thereby reducing the cost of construction.

6. Computer control of wood processing. A dynamic process control mathematical model for drying wood has been developed. Using two computer simulations and a dynamic programming decision model, optimum drying schedules can be developed for minimizing fixed output costs and maximizing unconstrained profit. Such programming for only this segment of the production process will result in cost savings equivalent to a 5 percent increase in dry kiln capacity. Appropriate modifications of the interaction factors of sampling, sorting, and scheduling can also increase the net value added by cut stock operations. This type of control is applicable to a large segment of the forest products industry and, if employed, will result in more efficient manufacturing practices.

C. Wood Fiber Products and Processes Development

1. Good quality pulps from southern pine thinnings. The potential annual supply of thinnings from southern pine plantations already in existence is about 3 million cords, almost 10 percent of the current annual pulpwood consumption of southern mills. There are increased pressures to pulp these younger trees in the rapidly expanding southern forest economy, resulting in increased interest in their pulping and papermaking qualities.

A study has shown that kraft pulps from pine thinnings can be used to make sheets that are softer and more flexible than from more mature trees. These qualities are important for tissue and toweling papers. The physical characteristics of the fibers from thinnings are similar to those of northern softwood pulps, and their flexibility aids in good sheet formation and surface smoothness, important in printing papers. Except for tear, papers and linerboard made from thinnings are as strong or stronger than those made from mature-tree woodpulp.

The finding that good pulp quality can be obtained from young trees should also encourage their removal as thinnings from natural, non-plantation forests and enhance the growth of remaining trees.

2. Improved printing properties of hardwood papers. The short, wide vessel elements peculiar to hardwood pulps, especially the abundant oaks, are a serious problem to the papermaker. They tend to be picked or lifted out of the paper surfaces by the ink during printing. This produces a low-quality print and contaminates the ink and printing equipment. Manufacturers of printing papers therefore prefer not to use oak-containing pulps. If they are used, a surface sizing with expensive chemicals must be applied to the paper to bind down fibers in the paper surfaces.

It has been determined that a commercially available refiner having a gyratory action on pulp can produce sufficient fibrillation of elements to increase the interlocking structure of the paper surface. Papers made with specially refined high-oak-content kraft pulps show much greater resistance to picking than control papers made with pulps refined conventionally. This improved bonding strength may permit reduction or elimination of the sizing now required. An important increase in use of hardwoods, especially the oaks, can be expected.

3. Washing pulped chips in the digester. Pilot-scale experiments have shown that washing of semi-chemically pulped chips in a horizontal digester to remove most of the pulping liquor is feasible. In-digester washing reduces the amount of processing otherwise necessary, and permits more economical and faster removal of pulping chemical for reuse. This not only reduces pulping costs and shortens overall process time, but helps curtail pollution. Pulp strength is not impaired.

The horizontal digesters used in the experiments eliminate one of the problems now blocking commercial in-digester washing of cooked semichemical pulp chips. This problem derives from the tendency of the chips to pack in a vertical digester of the type used in a kraft pulping. Packing makes it difficult to circulate wash water through the charge of chips. Results of the experiments will be valuable to industry in the design of commercial-scale equipment.

D. Wood Chemistry and Chemical Processing.

1. Quantitative method for analyzing tall oil. A quantitative method has been developed for the analysis of the resin and fatty acids in tall oil. For the first time, the amounts of these materials can be determined without prior separation. Tall oil is obtained from the black liquor of the kraft pulping process and annually yields some $100 million worth of useful industrial chemicals. These include drying oils, alkyd resins, soaps, and lubricants.

This new method will be valuable to the pulping industry in improving yields and quality and lowering costs of tall oil products. In order to do this, more needs to be known about the composition of intact softwood trees; the factors that contribute to variation of these components; the changes that take place during log and chip storage, during pulping processing and fractionation of the tall oil; and the composition of the end products.

This work is being done in cooperation with the Pulp Chemicals Association.

2. Wood as a livestock feed. Wood is going to play an increasingly important dual role in livestock feeding--as roughage and as a source of carbohydrate. Research under way shows that sawdust mixed with feed grain can provide a satisfactory roughage ration for ruminants. The importance of this lies in the current trend toward the finish-feeding of livestock with high-concentrate diets at large feed yards. Some yards are located in areas where hay roughage is scarce and costly but wood is relatively plentiful.

Wood may also furnish some of the carbohydrate required by ruminants. Animals cannot directly digest the carbohydrate in wood as they do in hay, but FPL chemists, working with University of Wisconsin scientists, have begun experiments with various methods of making wood digestible. Ammonia and alkali treatments have been found to about double the amount of material in aspen sawdust that can be digested. Aspen appears to be one of the few woods that are somewhat digestible without treatment. The experiments with modified woods are continuing.

This research is coordinated with similar investigations at the University of Wisconsin, Penn State University, and Auburn University. It is being supported in part by the Tennessee Valley Authority, which has broad interest in finding ways to expand utilization of extensive timber holdings in its area.

E. Wood Strength and Structural Concepts

1. Appalachian hardwoods for pallets. Recent investigations have demonstrated that the three most plentiful hardwoods in the Appalachian area have greater potential for pallets than had previously been thought. Oaks have had quite wide use, but the studies showed that use of lower grades with larger defects is feasible. Yellow poplar and, especially, hickory

have not been widely used. Both they and the oaks have several characteristics especially advantageous for pallet use--they are high in bending strength, toughness, and nailholding capacity. The studies showed that highly serviceable pallets are practical in reusable as well as expendable types. The pallet market used over 2½ billion board feet of lumber in 1966. The broadened outlook for these three species is extremely valuable because of the current heavy demand for hardwood pallets by the Department of Defense. Broader utilization of these species can combat shortages in pallet lumber supply and develop a more profitable economic structure in Appalachia.

2. Graphical solution for shear deflection in flexural members. Shear deflections are often more important in flexural members of wood and wood-base materials than in other structural materials. The added deflection due to shear typically is up to 10 percent of the total deflection. Methods for computing shear deflections are not generally well understood by engineers and architects. Research has now provided an easy graphic way to solve shear deflection problems. Since deflection limitations generally govern in design of wood beams, this method is helpful in refining critical design situations. It easily enables the designer to incorporate shear deflection in design, thereby providing more accurate predictions of the total deflection in structural members.

3. Bolt loads in multiple-bolt timber tension joints. Research studies on distribution of load among bolts, and on the effect that joint properties have on distribution of load have shown the following: (a) In joints containing six or more bolts in a row there is a highly uneven distribution of bolt loading--the two end bolts together usually carry more than half the load; (b) Having more than six bolts in a row does not substantially increase the elastic strength of the joint; (c) Small misalignment of boltholes may cause large shifts in bolt loads; (d) The most even distribution of load among bolts at butt joints occurs when extensional stiffness of the main member and both splice plates is equal; and (e) Only a slight redistribution of load from more heavily loaded end bolts to less heavily loaded interior bolts takes place when bolt bearing failure occurs. This previously unknown information will aid in development of more reliable design criteria for structural members where multiple bolt timber tension joints are involved.

4. Chemical treatments improve wet compressive strength of container-grade fiberboard. One of the factors that has limited broader use of fiberboard shipping containers is poor compressive strength under humid or wet conditions. Research has shown that a number of chemical treatments are effective in improving compressive properties of such containers when they are exposed to wet conditions. Top to bottom compressive strength of a container under wet conditions is greatly improved by addition of a phenolic resin to the chipboard. This also provides a possible means of improving the quality of container-grade solid fiberboards to meet specific requirements. The dollar value of solid fiberboard containers produced in the U. S. in 1966 exceeded $57 million. If application of these research findings increases use of solid fiberboard containers by only one percent it will represent an increase of one-half million dollars per year.

RPA 512 - IMPROVEMENT OF GRADES AND STANDARDS

A. Grading Systems Development

1. Southern pine. Accurate predictions of lumber yield, by grade, can be made with new grading systems for southern pine logs and trees. These simple, accurate and easy-to-use systems, based only on diameter, soundness, and a "clear-face" count, are described in a colored film produced in cooperation with the Federal Extension Service. They have been adopted as Forest Service standard and good acceptance is being shown by private industry, as well. Use of these new systems by both buyers and sellers of timber guarantees a more accurate prediction of lumber yield and value and will result in up to 10 percent higher returns.

Additional studies involving southern pine provide conversion factors for changes in lumber grade and volume in processing from rough-green to surfaced-dry and regression equations for estimating tree overruns for use with new tree grades.

2. Hardwood growing stock. A major problem is to identify those young hardwood trees that can be grown to provide the high-quality mature trees of the future. The supply of original old-growth hardwood forests is nearly exhausted. Specifications were developed for selecting those young trees possessing the greatest value potential. This three-grade system is correlated with the standard Forest Service grade specifications for hardwood sawlogs and each reflects the probability of a small tree yielding a grade-1, grade-2, or grade-3 butt log when it reaches 16 inches d.b.h. These growing-stock grades provide an effective means for using timber stand improvement operations for growing more grade-1 sawlogs and returning a profit on investment.

B. Lumber Grade Yield Development

1. Northern red oak. Existing lumber grade yield tables for the "upland red oak" group reflect an average yield of several species within that group, encompassing a wide range of quality. Research has now proven wide differences of value among species for the same log grade; hence, a single table penalizes some species and over-evaluates others. This study reports on the yields for northern red oak--by far the most important species within the upland group, both from volume cut and the greatest yield of higher grade lumber.

RPA 801 - HOUSING

1. Detailed plans for low-cost rural wood homes. Detailed plans for three low-cost rural homes, each employing a maximum amount of wood construction, were developed. Estimated construction costs for these 3-bedroom, 1,000 square foot homes are about $6.00 per square foot exclusive of land costs and exterior service connections. Designs have been accepted by the Farmers Home Administration for inclusion in their Plan Exchange System and arrangements are being made with that Agency to encourage construction of some of these houses to obtain accurate costs and more basic information. Arrangements are also being made to make the plans available through the Agricultural Research Service Plan Exchange System in conjunction with the Federal Extension Service.

2. Thermal conductivity measurement methods. Forest Service research has developed a reliable method for estimating thermal conductivity of wood-base fiber and particle panel materials on the basis of density. Results of this research have many applications and are already being used. For example, several trade associations have issued technical bulletins and design data sheets based on values determined by the study. The dollar value of this method is difficult to estimate but will certainly add up to large economic gains through more extensive use of particle board and hardboard due to availability of thermal conductivity factors.

3. Substantial savings made possible by Nu-Frame house construction system. Information and experience gained during construction of a 28- by 40-foot experimental house indicated that substantial savings can be made by adopting this house construction system. Time and material cost studies show a saving in on-site labor for walls and roofs as well as lower material costs. Although this system actually utilizes 2000 to 3000 more board feet of lumber, it is mostly in low-grade dimension and boards, which are not used in today's conventional wood-frame home. Estimated savings in materials is about $300 for the small 3-bedroom house. The overall savings using the Nu-Frame system is estimated to average about 10 percent (from 5 to 15 percent depending upon location) or about $2000 for a $20,000 house.

4. Thick particle boards as roof decking. Thick particle boards with pulp-chipcores have been evaluated as possible roof-decking material. Several fabrication variables and various kinds and combinations of face construction were investigated, with favorable results for many of the combinations tried. Possibilities are good that a properly made particle board 1-3/4 inches thick can be used for spans of as much as 48 inches. Evaluations were made of strength and stiffness in flexure, resistance to accelerated aging, internal bond strength, and dimension changes from ovendry to soak conditions. Possibility of producing a practical, dry-formed roof decking that can be laid directly on interior decorative beams appears promising.

8. Wood insulates for economies and comfort. One inch of wood has the thermal insulation value of approximately 16 inches of masonry. Low density wood-base materials have thermal insulation factors similar to those of mineral fiber insulations. The use of any thermal insulation in a building creates a need for moisture control not so necessary in uninsulated constructions which permit more air movement and have less condensation possibilities. Research has produced additional basic information on the thermal conductivity of all principal species of wood and wood-base materials, together with methods used for estimating heat loss through wood-framed walls, floor and roof structures. Methods for estimating fuel savings through proper thermal insulation, and surface temperatures for human comfort have also been developed.

9. New way to calculate temperature variation in wood-frame walls. Summer air conditioning and winter humidification have created potential moisture problems for the wood industry. Because temperature gradients contribute to the problems, information was sought on how climatic factors influence the distribution of temperature in wood-frame walls. An analog simulator, using an analogy between heat and electrical flow, was designed and constructed. From the information obtained from this computer, it is possible to determine the variation in temperature within wood-frame walls in most climates and use situations. Data are useful to builders and designers for calculating insulation requirements.

10. Reducing flammability of Douglas-fir plywood. Several chemicals and retention levels were evaluated in their ability to reduce the flammability of plywood. The more effective fire retardant chemicals were monoammonium phosphate and zinc chloride. At retentions over 2.0 pounds per cubic foot the smoke-index values were increased. Other chemicals reduced the smoke-index values unless extremely high retentions were involved, but these did not retard afterglow. All of the fire retardant chemicals investigated reduced the heat-index values with increasing retentions. The development of fire retardant formulations for wood is important in regard to both afterglow and smoke-index values. Results of this study will permit the increased efficiency of formulations for fire retardancy.

11. Laminated wood lasts 20 years. A study of laminated beams which had been treated with preservatives after gluing has shown that, after 20 years of exposure, the preservatives used had no deteriorating effects on the glue bonds. Slight decreases in shear strength that occasionally occurred were linked with certain species and treatments. The results of this research will be of outstanding value to communities considering the construction of buildings using treated laminated material, utilities constructing exterior structures, and housing construction that utilizes laminated material in exterior locations.

5. Onsite preservative treatments for exterior wood of buildings. Wood joints in residential frame-house construction--such as those in porches, exterior steps and columns, and window and door frames--are often vulnerable to wetting and decay. Laboratory bioassays to measure treatment effectiveness disclosed that certain ways of onsite preservative treating, such as might be done by the layman at the time of construction, or later as a maintenance measure, can give a high degree of protection to such parts. Findings of this study go far toward supplying much needed information about the potentials and limitations of onsite treating. The need is large because commercially treated wood for residences is not readily available in most localities.

6. Vapor barriers effect moisture content and serviceability of wood-frame walls. The permeability of vapor barriers used in wood-frame walls plays an important role in determining moisture accumulation within the wall. Studies of moisture distribution in three insulated conventional wood-frame wall panels in a test structure in Madison, Wisconsin, showed that when a sound vapor barrier was installed on the inside surface, the maximum moisture content remained at a low level. When vapor barriers were broken, leaked, or did not exist, excessively high moisture levels occured that could lead to poor serviceability of wood members. Wood sheathing reached a maximum moisture content of about 60 percent in early spring with no vapor barrier, about 24 percent with a broken barrier, and about 14 percent with a good barrier. The results further indicated that, although excessive moisture levels can be reached inside insulated wall sections during a cold winter, (as high as 17 percent), the drying effect of spring and summer weather reduced these to tolerable levels (about 10 percent).

7. New way to protect wood from decay. Dethiaminization, properly done, provides good decay protection without subsequent painting of the wood, but painting with an emulsion-type water-base paint seems to provide an additional margin of protection. Preliminary findings suggest that wood to be used above ground, even where conditions favor decay, can be effectively protected against decay with a nominal cost of chemical and a minimum of handling. Test units that were effectively dethiaminized were still in sound condition after eight years' exposure. This process is attractive because the treated wood contains no residual chemical; it is clean and paintable and presents no known problem in gluing. Preservative treatment by dethiaminization could bring about a direct saving of $5 million annually compared with present treating cost for lumber in above ground use. Considering the amount of lumber presently used untreated because of unavailability of treated stock, or because of difficulty in justifying the extra expense of pressure treatment for certain uses, there is a potential for much greater savings.

Publications - USDA and Cooperative Program

RPA 401 - NEW AND IMPROVED FOREST PRODUCTS

Wood Structure and Quality Relations

Dunmire, D. E., and Englerth, G. H. 1967. Predicting lumber cutting yields. USFS Res. Pap. NC-15.
Englerth, G. H. 1967. Taking the guesswork out of lumber yields. National Hardwood Lumber Assoc. Yearbook.
Foulger, A. N. 1968. Effect of aphid infestation on properties of grand fir. Forest Prod. J. 18(1).
Hallock, H. 1968. Observations on form of juvenile core in loblolly pine. USFS Res. Note FPL-0188.
Maeglin, R. R. 1967. Effect of tree spacing on weight yields for red pine and jack pine. J. of For. 65(9).
Malcolm, F. B. 1967. Warp. Plywood (India) 11(1).
Quirk, J. T., Kozlowski, T. T., and Blomquist, R. F. 1967. Location of failure in adhesive-bonded butt joints. USFS Res. Note FPL-0177.
Quirk, J. T., Kozlowski, T. T., and Blomquist, R. F. 1967. Effects of adhesive formulation and age in strength of bonded butt joints. USFS Res. Note FPL-0178.
Quirk, J. T., Kozlowski, T. T., and Blomquist, R. F. 1967. Transverse bonding of slash pine joints. Forest Prod. J. 17(12).
Quirk, J. T., Kozlowski, T. T., and Blomquist, R. F. 1968. Contributions of end-wall and lumen bonding to strength of butt joints. USFS Res. Note FPL-0179.
Schumann, D. R., and Englerth, G. H. 1967. Yields of random width dimension from 4/4 hard maple lumber. USFS Res. Pap. FPL-81.
Schumann, D. R., and Englerth, G. H. 1967. Dimension stock yields of specific width cuttings from 4/4 hard maple lumber. USFS Res. Pap. FPL-85.
Smith, D. M. 1967. Microscopic methods for determining cross sectional cell dimensions. USFS Res. Pap. FPL-79.
Wolter, K. E. 1968. A new method for marking xylem growth. Forest Science 14(1).

Solid Wood Processes and Products Development

Barger, R. L. 1967. Veneer volume and grade recovery from ponderosa pine in the Southwest. USFS Res. Note RM-88.
Beall, F. C. 1968. Specific heat of wood--further research required to obtain meaningful data. USFS Res. Note FPL-0184.
Blew, J. O. 1967. Comparison of wood preservatives in stake tests. USFS Res. Note FPL-02.
Blew, J. O., and Davidson, H. L. 1967. Comparison of wood preservatives in Mississippi post study. USFS Res. Note FPL-01.
Blew, J. O., Roth, H. G., and Davidson, H. L. 1967. Preservative retention and distribution in several western conifers. Proc. of Amer. Wood Preservers' Assoc. Vol. 63.

Brenden, J. J. 1967. Effect of fire retardant and other inorganic salts on pyrolysis products of ponderosa pine at 250° and 350° C. USFS Res. Pap. FPL-80.

Brenden, J. J. 1967. Calorific values of the volatile pyrolysis products of wood. Combustion and Flame 11(5).

Chudnoff, M., Boone, R. S., and Goytia, E. 1967. Preservative treatments and service life of fence posts in Puerto Rico. USFS Res. Pap. ITF-4.

Chudnoff, M., and Goytia, E. 1967. The effect of incising on drying, treatability, and bending strength of posts. USFS Res. Pap. ITF-5.

Chudnoff, M., and Goytia, E. 1967. Spindle carving of tropical hardwoods. Turrialba 17:430-435.

Claxton, H. D. 1968. A dynamic programming decision model and computer simulation of the cedar pencil slat drying process. Ph.D. dissertation, Univ. of Calif.

Comstock, G. L. 1967. Longitudinal permeability of wood to gases and non-swelling liquids. Forest Prod. J. 17(10).

Duncan, C. G. 1967. Effect of light on the rate of decay of the three wood-destroying fungi. Phytopathology 57(10).

Dunmire, D. E., and Englerth, G. A. 1967. Development of a computer method for predicting lumber cutting yields. USFS Res. Pap. NC-15.

Efolliott, P. F., and Barger, R. L. 1967. Occurrence of stem features affecting quality in cutover Southwestern ponderosa pine. USFS Res. Pap. RM-28.

Eslyn, W. E. 1967. Outside storage of hardwood chips in the Northeast. II. Microbiological Effects. TAPPI 50(6).

Eslyn, W. E. 1968. Utility pole decay--Part I: Appraisal of a device for nondestructive detection of decay. Wood Science and Technology. Vol. 2.

Gatchell, C. J. 1967. Machine-driving pressure-treated wood posts: A way to reduce highway guardrail costs. Wood Preserving News 45(8):13-15.

Gettens, R. 1967. Comparative growth of phenol-oxidase negative and positive wood-decaying basidiomycetes on lignin-related phenols. Thesis, Univ. of Wis.

Heebink, B. G. 1968. Wax in particleboards. Proc. of First Symposium on Particleboard. Pullman, Wash.

Kimball, K. E. 1968. Accelerated methods of drying thick-sliced and thin-sawed loblolly pine. Forest Prod. J. 18(1).

Koch, P. 1967. Too many crooked small logs? Consider a shaping-lathe head-rig. South. Lumberman 215(2680):147-149.

Koch, P. 1967. Location of laminae by elastic modulus may permit manufacture of very strong beams from rotary-cut southern pine veneer. USFS Res. Pap. SO-30.

Kotok, E. S. 1967. History of the forest utilization service. Speech presented at the 22nd Annual Northwest Wood Prod. Clinic and Forest Prod. Research Society Meeting, April.

Kotok, E. S., and Benson, R. E. 1967. 100-level construction--a novel marketing concept. Forest Prod. J. 17(9):86-90.

Lowery, D. P., and Kotok, E. S. 1967. Evaluation of a microwave wood moisture meter. Forest Prod. J. 17(10):47-51.

Lowery, D. P., and Wellner, C. A. 1967. Spiral grain--a cause of pole twisting. USFS Res. Pap. INT-38.

Lutz, J. F. 1967. A survey of some developments in slicing and veneer cutting. Proc. of Section 41, Forest Products, International Union of Forestry Research Organization, XIV.

Lutz, J. F., Mergen, A., and Panzer, H. 1967. Effect of moisture content and speed of cut on quality of rotary-cut veneer. USFS Res. Note FPL-0176.

McMillen, J. M. 1967. Seasoning and handling of ramin. USFS Res. Note FPL-0172.

McMillen, J. M. 1968. Transverse strains during drying of 2-inch ponderosa pine. USFS Res. Pap. FPL-83.

McMillen, C. W. 1968. Cross wood characteristics affecting properties of handsheets made from loblolly pine refiner groundwood. TAPPI 51(1):51-56.

Merz, R. W. 1967. How to estimate cost of producing dimension parts. NC Forest Expt. Sta. Leaflet.

Merz, R. W., and Cooper, G. A. 1968. Effect of polyethylene glycol on stabilization of black oak blocks. Forest Prod. J. 18(3):55-59.

Mueller, L. A., and Kovner, J. L. 1967. Lumber production from selected Black Hills ponderosa pine. USFS Res. Pap. RM-31.

Panek, E., and Roth, H. G. 1968. The vacuum treatment of lumber. Proc. of 1968 National AWPA Meeting.

Peters, C. C. 1967. Thick slicing at Forest Products Laboratory. Proc. of Wood Machining Seminar, Univ. of Calif., Richmond, Calif. Oct.

Peters, C. C., Zenk, R. R., and Mergen, A. 1968. Effects of roller-bar compression and restraint in slicing wood 1-inch thick. Forest Prod. J. 18(1).

Rice, W. W., and Cooper, G. A. 1967. Small shop laminating press. Forest Prod. J. 17(11):59-60.

Sesco, J. A., and Dunmire, D. E. 1967. Market opportunities for hickory stadium seat slats. South. Lumberman 215(2680):165-166.

Steward, H. A. 1967. An analysis of orthogonal wood cutting against the grain. M.S. Thesis, Univ. of Mich.

Tang, W. K., and Eickner, H. W. 1968. Effect of inorganic salts on pyrolysis of wood, cellulose, and lignin determined by differential thermal analysis. USFS Res. Pap. FPL-82.

Troxell, H. E., and Mueller, L. A. 1968. Solar lumber drying in the Central Rocky Mountain region. Forest Prod. J. 18(1).

Vick, C. B., Gaby, L. I., and Baechler, R. H. 1967. Treatment of hardwood fence posts by the double-diffusion process. Forest Prod. J. 17(12).

Weldon, D. 1968. Volume and location of southern yellow pine sawdust in east Texas. Texas Forest Service Cir. 106.

Wengert, E. M. 1968. Energy losses in solar drying. Masters Thesis, Colo. State Univ.

Yerkes, V. P. 1967. Effect of seasonal stem moisture variation and log storage on weight of Black Hills ponderosa pine. USFS Res. Note RM-96.

Vick, C. B., Gaby, L. I., and Baechler, R. H. 1967. Eleventh year service report-treatment of hardwood fenceposts by double diffusion process. Forest Prod. J. 17(12):33-35.

Wood Fiber Products and Processes Development

Fahey, D. J. 1967. Improvements in cylinder board from interply chemical additions. Paper Trade J. 15:34.

Fahey, D. J., and Laundrie, J. F. 1968. Kraft pulps, papers, and linerboards from southern pine thinnings. USFS Res. Note FPL-0182.

Horn, R. A., and Simmonds, F. A. 1968. Microscopical and other fiber characteristics of high-yield sodium bisulfite pulps from Balsam fir. TAPPI 50(1).

Keller, E. L., and Fahey, D. J. 1968. Magnesium bisulfite pulping and papermaking with southern pine. TAPPI 51(2).

Laundrie, J. F. 1967. Kraft pulping of digger and knobcone pine. USFS Res. Note FPL-0181.

Rankin, J. C., Hofreiter, B. T., Chilson, W. A., and Fahey, D. J. 1967. On machine evaluation of modified wheat flours as surface sizes for paper. TAPPI 50(6).

Wood Chemistry and Chemical Processing

Clark, I. T., and Green, J. 1968. Production of phenols by cooking kraft lignin in alkaline solutions. TAPPI 51(1).

Cote, W. A., Day, A. C., Kutscha, N. P., and Timell, T. E. 1967. Studies on compression wood. V. Nature of the compression wood formed in the early springwood of conifers. Holzforschung 21:180.

Cote, W. A., Day, A. C., and Timell, T. E. 1968. Studies on compression wood. VII. Distribution of lignin in normal and compression wood of tamarack. Wood Sci. and Tech. 2:13.

Cote, W. A., Kutscha, N. P., Simson, B. W., and Timell, T. E. 1968. Studies on compression wood. VI. Distribution of polysaccharides in the cell wall of tracheids from compression wood of balsam fir. TAPPI 51(1)

Cote, W. A., Pickard, P. A., Timell, T. E. 1967. Studies on compression wood. IV. Fractional extraction and preliminary characterization of polysaccharides in normal and compression wood of balsam fir. TAPPI 50(7).

Feather, M. S., and Harris, J. F. 1967. Chromatographic isolation of some cellulose oligosaccharides. USFS Res. Note FPL-0161.

Feather, M. S., and Harris, J. F. 1967. The preparation and purification of cellobiose-1-C^{14}. USFS Res. Note FPL-0168.

Feather, M. S., and Harris, J. F. 1967. The partial hydrolysis and acetolysis of cellotriose-1-C^{14}. J. Amer. Chem. Soc. 89(22).

Feist, W. C., and Tarkow, H. 1967. A new procedure for measuring fiber saturation points. Forest Prod. J. 17(10).

Fracheboud, M., Rowe, J. W., Scott, R. S., Fanega, S. M., Buhl, A. J., and Toda, J. K. 1968. New sesquiterpenes from the yellow wood of slippery elm. (Ulmus rubra Muhl). Forest Prod. J. 18(2).

Karanjgaokar, C. G., Radhakrishnan, P. V., and Venkataraman, K. 1967. Morelloflavone, a 3-(8-) flavonylflavanone, from the heartwood of Garcinia morella. Tetrahedron 33:3195.

Millett, M. A., Western, L. J., and Booth, J. J. 1967. Accelerated aging of cellulosic materials--design and application of a heating chamber. TAPPI 50(11).

Moore, W. E., and Johnson, D. B. 1967. Procedures for the chemical analysis of wood and wood products. FPL Manual, 382 pages.

Nestler, F. M., and Zinkel, D. F. 1967. Quantitative gas-liquid chromatography of fatty and resin acid methyl esters. Anal. Chem. 39(8).

Pew, J. C. 1967. Lignin: an inviting storehouse. Agric. Sci. Rev. 5(4).

Pew, J. C., and Connors, W. J. 1967. New structures from the dehydrogenation of model compounds related to lignin. Nature 215(5101).

Rowell, R. M., and Feather, M. S. 1967. Synthesis and properties of anomerically unsubstituted hepta-o-acetyl disaccharides. Carbohy. Res. 4:486.

Scott, R. W., Moore, W. E., Effland, M. J., and Millett, M. A. 1967. Ultraviolet spectrophotometric determination of hexoses, pentoses, and uronic acids after their reaction with concentrated sulfuric acid. Anal. Biochem. 21(1).

Seikel, M. K., Hostettler, F. D., and Johnson, D. B. 1968. Lignans of Ulmus thomasii heartwood. I thomasic acid. Tetrahedron 24:1475.

Simson, B. W., and Timell, T. E. 1967. A method for determination of the carbohydrate composition of microgram quantities of plant tissues. TAPPI 50(10).

Weatherwax, R. C., and Tarkow, H. 1968. Cell wall density of dry wood. Forest Prod. J. 18(2).

Zinkel, D. F., Lathrop, M. B., and Zank, L. C. 1968. Preparation and gas chromatography of the trimethylsilyl derivatives of resin acids and the corresponding alcohols. J. Gas Chromatography 6(3).

Wood Strength and Structural Concepts

Bohannan, Billy. 1968. Structural engineering research in wood. J. of the Struct. Div. Proc. of the Amer. Soc. of Civil Eng. 94:403-416.

Cramer, C. O. 1967. An analytical and experimental examination of wood tension joints having a large number of bolts. Thesis, Univ. of Wis.

Godshall, W. C. 1967. Construction and evaluation of loading heads for compression tests of corrugated fiberboard pads. FPL Rept.

Hilbrand, H. C. 1967. A graphical solution for shear deflection in flexural members. Forest Prod. J. 17(6):61-62.

Jordan, C. A. 1968. Container effects in cushioned packages: urethane foam cushioning applied as side pads. USFS Res. Pap. FPL-91.

Kurtenacker, R. S., Heebink, T. B., and Dunmire, D. E. 1967. Appalachian hardwoods for pallets--a laboratory evaluation. USFS Res. Pap. FPL-76.

Lewis, W. C. 1967. Thermal conductivity of wood base fiber and particle panel materials. USFS Res. Pap. FPL-77.

Lewis, W. C. 1968. Hardness modulus as an alternate measure to the standard Janka ball for wood and wood-base materials. USFS Res. Note FPL-0189.

FOREST ENGINEERING
(RPA 302 NEW AND IMPROVED FOREST ENGINEERING SYSTEMS)

USDA and Cooperative Program

Location of Intramural Work by States	Scientist Man-Years FY 1968
Alabama	2.7
Michigan	2.5
Montana	3.0
Washington	5.0
West Virginia	3.0
Total	16.2

Intramural program is supplemented by extramural support representing
(a) NO SMY's at State Agricultural Experiment Stations,
(b) 2 SMY's at other U. S. institutions and
(c) P.L. 480 funds in NO countries representing NO U. S. dollars equivalent.

Problems and Objectives

About 1.6 billion dollars annually is required to harvest and transport the Nation's timber crop to primary processing plants, about 60% of the total cost of the raw material at the plant--a much higher percentage than for competing industries. An estimated 585 million cubic feet of annual allowable cut in the West is currently non-loggable with conventional systems. A large percentage of the standing timber harvested is left in the woods in the form of tops, timber culls and debris. Worker productivity is low; woods labor supply is dwindling; woods workers' accident rate is one of the highest in industry; all of which tend to depress rural forest economy. Many logging operations are incompatible and/or damaging to other forest values such as recreation, natural beauty, and water.

The major objectives of Forest Engineering Research are to develop new and improved engineering systems and to evaluate alternative ways to:

1. Reduce the cost, and impacts on other uses, of timber harvest and transport.
2. Obtain economic access to inoperable timber.
3. Mechanize--and automate--forestry operations.
4. Improve woods worker productivity and safety.
5. Develop economic removal systems for logging wastes.

Progress - USDA and Cooperative Program

A. Engineering Systems for Difficult Access Areas

1. Thinning with skylines on steep slopes without damage. Field tests confirmed that timber on steep slopes can be efficiently thinned without significant damage to the residual stand by means of proper felling and well designed and operated skyline crane yarding systems. This finding should contribute to improved forest management practices and possible increased allowable cuts.

2. Computers reduce cost of skyline design. Research to date has shown it is technically feasible to employ a computer to analyze topography and calculate skyline capabilities for each location, as well as to present the results in a graphic manner, by means of an electronic plotter. This procedure will result in substantial cost savings.

B. Engineering Systems for Steep Erosible Slopes

1. Wood-chip pipeline transport can be cheaper than truck or rail. A model was developed to determine transportation costs for hydraulic pipelines with optimum pipe diameters and wood-chip concentrations, and comparisons made with rail and trucking costs. Costs per ton-mile for lines transporting 1000-2000 tons per day (oven-dry basis) were found to

be generally cheaper than truck or rail up to distances of about 60 miles, except for areas in the southeastern U. S. where rail rates for 2000 tons per day were cheaper for distances over 40 miles.

2. Parametric analysis aids estimating tractor skidding costs. A parametric analysis procedure has been used to develop a series of nomographs and charts for quick and easy detection of trade-offs between tractor size. The nomographs are entered with information about terrain, skidding distance, slope, operator efficiency, and hourly operating costs--they yield cost per thousand board feet.

C. Engineering Systems for Thinning Dense Stands and Converting Sites

1. New weight-sensing device developed. More exact weight and center of gravity information are needed by designers of log and tree handling equipment. A dual-range strain gage transducer has been developed as a weight-sensing device for weighing trees and tree-length logs. It functions with satisfactory repeatability and accuracy within tolerable limits over a temperature range of 10° - 90°F and for loads from 8000 pounds to 100 pounds. Two weight ranges are provided, 0-2000 and 2000-8000 pounds.

2. Can power requirements for chipping be reduced? Experimental results showed that the power requirements for any species would minimize with decreasing knife sharpness angle, increasing chip length, and increasing side spout angle. The decrease in power with increasing side angle indicates that a significant savings in power might result by chipping parallel to the grain.

D. Engineering Systems for Appalachia

1. Special design wheeled skidders may be needed in Appalachia. Conditions inherent to Appalachia logging--steep slopes and heavy logs--were found to significantly affect many logging functions performed by the wheeled skidder. Machine performance was linked to slope and tree weight in most operations. The performance level of manual operations by crews was significantly tied to slope steepness. Experiments showed more consideration should be given to machine center of gravity and to horsepower when selecting or designing equipment for Appalachia use. Mechanical difficulties experienced showed that winch line fouling on large diameter wheels could cause production slow-downs or present safety hazards.

2. Belt conveyors may move logs in the future. A feasibility study showed that a conveyor system was almost unlimited in the amount of wood it could handle, relative to a trucking system. Steepness of slope is a primary technical difficulty. The study showed that while transporting logs by conveyor is not presently feasible, the costs are not far removed

from trucking costs. If trucking costs increase, and technical problems of conveyor systems overcome, conveying of logs in the future could be practical.

E. Engineering Systems for Intensive Forest Management

1. Mechanical harvesting of cones eliminates tree climbing. Studies have shown that longleaf and slash pine cones can be detached from trees by using commercially available variable-frequency tree shakers which simulate a "twist-pull" technique. Other southern pine species require a sharp blow struck parallel to the twig. Commercial shakers have been adjusted to do a fair job of detaching these cones--but they are inefficient at producing the appropriate vibration. In a full production operation, 14,600 bushels of slash pine cones were collected in a two-week period using five tree shakers.

2. Machine for cutting heavy undergrowth now available. A new type rotary cutter blade which cuts "with the action of an axe" has been designed and successfully tested in heavy undergrowth. The tractor-cutter system was designed initially for preparing access trails through palmetto in naval stores operations but is adaptable to other purposes, such as clearing of recreation areas.

3. Wood-chip pipeline transportation attractive in Alabama. A systems analysis of the economics of wood-chip pipeline transportation in Alabama indicated that operational costs will tend to level off, or even decrease, throughout the life of the line, since electrical energy costs, which make up most of the operational costs have tended to go down.

Publications - USDA and Cooperative Program

Engineering Systems for Difficult Access Areas

Binkley, Virgil W. and Williamson, Richard L. 1968. Skyline effective for thinning Douglas-fir on steep slopes. Forest Industries, 2 pp., illus. Feb.

Engineering Systems for Steep Erosible Slopes

Gardner, R. B. 1967. Exploratory analysis of crawler-tractor skidding in Montana. American Soc. Agr. Engrs. Proceedings 60th Annual Meeting, June 1967.

Hunt, W. A. 1967. Economic analysis of a wood-chip pipeline. Forest Products J. 17(9): 68-74. Sept.

Engineering Systems for Thinning Dense Stands and Converting Sites

Arola, Rodger A. 1968. A dual-range strain gage weighing transducer employing automatic switching. North Central Forest Exp. Station Research Note NC-44, 4 pp.

Erickson, John R. 1967. Cross-cut shearing of wood. XIV International Union of Forestry Research Organizations Congress Papers, Vol. VIII Munich, Germany. P. 324-337. Sept.

Papworth, R. L. and Erickson, John R. 1967. Can power requirements for chipping be reduced? Pulp & Paper 41(23): 40-41

Engineering Systems for Appalachia

Dodd, S. J. and Gochenour, D. L. 1967. A feasibility study as to the practicability of general utilization of belt conveyors in Appalachia as a large volume means of conveying forest material. Engineering Experiment Station Report. West Va. Univ. 103 pp. illus.

Gibson, H. G., Gochenour, D. L., Hartman, R. L., and Parker, H. W. 1967. Wheeled skidder performance in steep terrain. ASAE Paper No. 67-627. Proceedings Annual Meeting, Detroit, Mich. Dec. 13, 1967. 26 pp. illus.

Parker, H. W., Gibson, H. G., and Phillips, R. A. 1967. Wheeled skidder experiments in Appalachia. XIV IUFRO-Kongress, Munich, Oct. pp. 364-384.

Engineering Systems for Intensive Forest Management

Hool, James N. 1967. Wood-chip transportation by hydraulic pipeline. Alabama Forest Products 10(7): 111-112. 1967-68 Directory.

Richardson, Boone Y. and Stokes, C. M. 1967. A machine for cutting pine forest undergrowth. Naval Stores Review and Terpine Chemicals. 77(8): 7 and 17. illus. November.

Richardson, Boone Y. 1967. Shaking trees to collect pine cones. Southern Lumberman 215 (2680): 140-141 illus. Dec. 15.

Taylor, Heyward T. Jr. 1967. Progress in seed collection methods. Proceedings Southeastern Area Forest Nurserymen's Conference 67-68.

FOREST ECONOMICS AND MARKETING RESEARCH

FOREST SURVEY

(RPA 110 - APPRAISAL OF FOREST AND RANGE)

USDA and Cooperative Program

Location of Intramural Work	Scientist Man-Years F.Y. 1968
Alaska	2.8
Louisiana	6.0
Minnesota	5.0
North Carolina	5.0
Oregon	6.6
Pennsylvania	6.0
Utah	7.8
Washington	3.0
Total	42.2

Intramural program is supplemented by extramural support representing (a) 0 SMY's at State Agricultural Experiment Stations, (b) 0 SMY's at other U.S. institutions and (c) P.L. 480 funds in 0 countries representing 0 U.S. dollars equivalent.

Problems and Objectives

The United States has some 500 million acres of commercial forest land which vary greatly in productivity and availability for industrial use. These forests also show widely divergent and rapidly changing trends in growth and depletion. At the present time about $700 million is being spent annually on the protection, development, and management of forest lands for timber production. In addition, capital expenditures in the timber-based industries such as the lumber and wood products and paper and allied products industries amount to about $2 billion a year.

The general objectives of Forest Survey research are to:

1. Collect and compile basic information relating to present and prospective supplies and demands for timber for individual States and for the Nation,

2. Make technical interpretations of the collected data on timber inventories, growth, marketing, and timber use that will provide a sound basis for forest policy and program decisions on national, State, and local levels,

3. Accelerate the Survey to provide up-to-date appraisals of the timber situation,

and

4. Intensify the Survey to provide more localized information needed by public and private organizations in carrying out forestry programs, particularly programs concerned with forest industrial development in rural areas and regional planning.

Progress--USDA and Cooperative Programs

1. Field surveys conducted in 12 States. During the past year the equivalent of approximately 49 million acres of commercial forest land was inventoried. Field surveys were conducted in Alaska, Arkansas, California, Idaho, Mississippi, Maine, Nevada, New York, Ohio, South Carolina, Washington, and Wisconsin. Reports appraising the forest situation were issued for 8 States or portions of States.

Resurveys of States are being made at intervals of 8 to 15 years. Because of rapid changes in timber cut and growth, more frequent coverage is needed to provide guides for forestry and rural development programs.

2. Available timber supplies can support modest increase in demands. Analysis of the currently available forest resource data shows that timber supplies in the United States are sufficient to support a modest increase in timber demands. The expansion potentials, however, are limited to softwoods in the South, hardwoods in the North, and National Forest softwood timber in the Rocky Mountain area and Coastal Alaska where the allowable cut is not fully utilized.

Projected timber supplies show a continuing rise over the next decade or two. But this rise fails to match the anticipated increase in demands on the Nation's forests for saw logs, veneer logs, pulpwood, and other timber products. After about 1980, projected timber supplies fall increasingly short of the rising timber demands. By 2000, assuming continuation of the levels of forest management prevailing in 1962, the shortfall would be about 4 billion cubic feet.

3. Forest Survey of Alaska completed. The first survey of the forest resources of Coastal Alaska--some 5.7 million acres of commercial forest land and 185 billion board feet of sawtimber--showed that the resource could support at least a doubling of the current log harvest of about 400 million board feet. The 22.5 million acres of commercial forest land in the interior, with 31 billion board feet of sawtimber, is largely economically inoperable at this time.

4. Employment in forest industries to decline in the Pacific Northwest and California. An analysis of the future of timber resources and forest products industries of the Columbia-North Pacific Water Resource Region indicates that the available log harvest will decline some 11 percent by 2020. This drop is expected to take place primarily in western Oregon--now the major center of the forest industry--because of the declining cut from private timber lands. In Washington and eastern Oregon, log production is expected to show a small rise. By 2020, employment in the forest industries in the Pacific Northwest is expected to be only about two-thirds of the 1965 level because of the drop in log production and increased productivity.

A similar analysis for the California Water Resources Region indicates a slight increase in the total log harvest by the year 2020. While a 15-percent decline in use of roundwood for lumber and miscellaneous wood products is expected, use of roundwood and residues for pulp is expected to increase substantially. Employment in the lumber and wood products industry is projected to decline by over 50 percent, whereas, employment in the pulp and paper industry is expected to triple. Total payrolls in the pulp and paper industry are projected to increase 6 to 8 times the 1965 level.

5. Timber volume, cut, and growth increasing in Michigan. As part of a continuing program to evaluate the timber resource situation in the North Central Region, statistics were collected on the timber resource and timber use in Michigan, pulpwood production and consumption in all States in the Region, and lumber production in northern Minnesota. In Michigan, forest growing stock volume increased 40 percent between 1955 and 1966, and sawtimber increased 42 percent. Timber cut and growth also increased. Pulpwood production reached a new high of 4.25 million cords in 1966 in the Lake States--17 percent above the previous high in 1964. Lumber production dropped 15 percent in northern Minnesota between 1960 and 1965.

6. Pennsylvania's forest resources can support new timber-based industry. A recent survey of the forest resources of Pennsylvania showed that annual timber growth was much greater than the annual cut and that substantial supplies of timber are available to support new wood-using industries. Most of the current growth is concentrated on hardwood poletimber trees or on small-size sawtimber trees less than 15 inches in diameter. Nonetheless, volumes of larger sawtimber trees--most in demand for manufactured products such as lumber and veneer--also increased about 20 percent in the 10 years between surveys.

7. Another record-breaking year for the South's booming pulpwood industry. The South's pulpwood industry again had a record-breaking year in 1966 when a total of 33.1 million cords of wood were produced. This amount, nearly 61 percent of the Nation's total, went to 87 mills in the 12 southern States and 10 mills outside of the South. Expansion of existing plant facilities, plus the addition of 5 new mills during the year, increased the South's pulping capacity to 64.7 thousand tons per day--a gain of more than 9 percent. Pulpwood production in the South rose 7 percent, or 2.3 million cords. Pine roundwood accounted for 57 percent of the increase, residues from other wood-using industries 26 percent, and hardwood roundwood 17 percent. Gains in pulpwood production were reported in 10 of the 12 southern States.

8. Land clearing in the Mississippi Delta having major impacts on hardwood timber supplies. In the Delta Region of Mississippi, clearing of land for agriculture is having major impacts on hardwood timber supplies. More than one-fifth of the commercial forest acreage in the State's delta has been cleared in the last 10 years. This is a continuation of a trend that has been going on since the first forest survey of Mississippi in 1932. However, the rate of clearing in the last decade was nearly 4 times that noted in earlier surveys. As a result, timber removals from this important timber-producing region, and from the delta regions of other southern States, are now substantially greater than growth.

9. Midsouth mills paid record prices for delivered pulpwood in 1966. In 1966 the average price for hardwood pulpwood was $15.04 a cord. Pine bolts sold for $16.87 a cord, or $.57 above 1965 and a new high for the Midsouth. Green chips averaged $6.58 per ton for pine and $5.50 for hardwood.

Publications - USDA and Cooperative Program

RPA 110 - APPRAISAL OF FOREST AND RANGE RESOURCES

Bare, B. Bruce, and Stone, Robert N. 1968. A computer program for mapping Forest Survey type information. North Central Forest Expt. Sta., St. Paul, Minn. U.S. Forest Service Research Note NC-45, 4 pp., illus.

Beltz, R. C., and Christopher, J. F. 1967. Land clearing in the Delta region of Mississippi, 1957-1967. Southern Forest Expt. Sta., New Orleans, La. U.S. Forest Service Research Note SO-69, 3 pp., illus.

Berger, John M. 1968. Timber resource statistics for central Oregon, 1965. Pacific Northwest Forest & Range Expt. Sta., Portland, Oregon. U.S. Forest Service Resource Bull. PNW-24, 38 pp.

Blyth, James E. 1967. Pulpwood production and consumption in the North Central Region by county. North Central Forest Expt. Sta., St. Paul, Minn. U.S. Forest Service Resource Bull. NC-3, 27 pp., illus.

Blyth, James E. 1967. Rising pulpwood prices stimulate largest Lake States pulpwood harvest, 1966. North Central Forest Expt. Sta., St. Paul, Minn. U.S. Forest Service Research Note NC-31, 3 pp.

Christopher, J. F. 1967. 1966 pulpwood prices in the Midsouth. Southern Forest Expt. Sta., New Orleans, La. Southern Pulp and Paper Manufacturer 30(10):42, Oct. 1, 1967.

Ferguson, Roland H. 1968. The timber resources of Pennsylvania. Northeastern Forest Expt. Sta., Upper Darby, Pa. U.S. Forest Service Resource Bull. NE-8, 147 pp., illus.

Ferguson, Roland H. 1967. The timber resources of Maryland. Northeastern Forest Expt. Sta., Upper Darby, Pa. U.S. Forest Service Resource Bull. NE-7, 93 pp., illus.

Haines, William H. B. 1967. Forest statistics for the Piedmont of South Carolina, 1967. Southeastern Forest Expt. Sta., Asheville, N.C. U.S. Forest Service Resource Bull. SE-9, 35 pp.

Hanks, Leland F., and Swanson, Carl W. 1967. Pacific Northwest Forest & Range Expt. Sta., Portland, Oregon. U.S. Forest Service Research Paper PNW-51, 29 pp., illus.

Honda, Nobuo; Wong, W.H.C., Jr.; and Nelson, R. E. Plantation timber on the Island of Kauai--1965. Pacific Northwest Forest & Range Expt. Sta., U.S. Forest Service Resource Bull. PSW-6, 34 pp., illus.

Hutchison, O. Keith. 1967. Alaska's forest resource. Pacific Northwest Forest & Range Expt. Sta., Portland, Oregon. U.S. Forest Service Resource Bull. PNW-19, 74 pp., illus.

Kingsley, Neal P., and Dickson, David R. 1967. Pulpwood production in the Northeast--1965. Northeastern Forest Expt. Sta. Upper Darby, Pa.

U.S. Forest Service Resource Bull. NE-6, 36 pp., illus.

Knight, Herbert A., and McClure, Joe P. 1967. Virginia's timber, 1966. Southeastern Forest Expt. Sta., Asheville, N.C. U.S. Forest Service Resource Bull. SE-8, 47 pp.

Knutson, Robert G. 1967. Lake States veneer log production shows increase in 1965. North Central Forest Expt. Sta., St. Paul, Minn. U.S. Forest Service Research Note NC-26, 3 pp., illus.

LaBau, Vernon J. 1967. Literature on the Bitterlich method of forest cruising--a bibliography. Pacific Northwest Forest & Range Expt. Sta., Portland, Oregon. U.S. Forest Service Research Paper PNW-47, 20 pp.

Ostrom, Arnold J. 1967. Forest area in Michigan counties, 1966. North Central Forest Expt. Sta., St. Paul, Minn. U.S. Forest Service Research Note NC-38, 4 pp., illus.

Ostrom, Arnold J. 1967. Forest cover types by counties, Michigan, 1966. North Central Forest Expt. Sta., U.S. Forest Service Research Note NC-41, 4 pp., illus.

Oswald, Daniel D. 1968. Preliminary timber resource statistics for Humboldt County, California. Pacific Northwest Forest and Range Expt. Sta., Portland, Oregon. U.S. Forest Service Resource Bull. PNW-23, 8 pp.

Peters, Robert C., and Wilson, Robert W., Jr. 1967. The northeastern forest-inventory data-processing system. III. Operation of subsystem EDIT. Northeastern Forest Expt. Sta., Upper Darby, Pa. U.S. Forest Service Research Paper NE-71, 31 pp., illus.

Peters, Robert C., and Wilson, Robert W., Jr. 1967. The northeastern forest-inventory data-processing system IV. Information for programmers--subsystem EDIT. Northeastern Forest Expt. Sta., Upper Darby, Pa. U.S. Forest Service Research Paper NE-72, 9 pp., illus.

Peters, Robert C., and Wilson, Robert W., Jr. 1967. The northeastern forest-inventory data-processing system VI. Operation of subsystem TABLE. Northeastern Forest Expt. Sta., Upper Darby, Pa. U.S. Forest Service Research Paper NE-74, 25 pp., illus.

Peters, Robert C., and Wilson, Robert W., Jr. 1967. The northeastern forest-inventory data-processing system. VII. Information for programmers--subsystem TABLE. Northeastern Forest Expt. Sta., Upper Darby, Pa. U.S. Forest Service Research Paper NE-75, 22 pp.

Peters, Robert C., and Wilson, Robert W., Jr. 1967. The northeastern forest-inventory data-processing system. IX. Operation of subsystem OUTPUT. Northeastern Forest Expt. Sta., Upper Darby, Pa. U.S. Forest Service Research Paper NE-77, 18 pp., illus.

Peters, Robert C., and Wilson, Robert W., Jr. 1967. The northeastern forest-inventory data-processing system. X. Information for programmers--subsystem OUTPUT. Northeastern Forest Expt. Sta., Upper Darby, Pa. U.S. Forest Service Research Paper NE-78, 15 pp.

Rawie, Carl D., and Blyth, James E. 1967. Northern Minnesota lumber production declines from 1960 to 1965. North Central Forest Expt. Sta., St. Paul, Minn. U.S. Forest Service Research Note NC-30, 4 pp.

Sternitzke, H. S. 1967. East Texas pineywoods. Southern Forest Expt. Sta., New Orleans, La. U.S. Forest Service Resource Bull. SO-10, 30 pp.

Sternitzke, H. S. 1967. East Texas post oak region. Southern Forest Expt. Sta., New Orleans, La. U.S. Forest Service Resource Bull. SO-11, 8 pp.

Stone, Robert N. 1967. Forest stand-size trends in Upper Michigan, 1955-1966. North Central Forest Expt. Sta., St. Paul, Minn. U.S. Forest Service Research Note NC-39, 2 pp.

U.S. Forest Service. 1967. Alaska. Map of forest regions and types. Pacific Northwest Forest & Range Expt. Sta. 1 p.

Van Hooser, Dwane D., and Christopher, Joe F. 1967. Southern pulpwood production, 1966. Southern Forest Expt. Sta., New Orleans, La. U.S. Forest Service Resource Bull. SO-9, 23 pp., illus. (Cooperative publication between SE & SO Stations)

Van Sickle, C. C. 1967. East Oklahoma's timber harvest, 1965. Southern Forest Expt. Sta., New Orleans, La. U.S. Forest Service Research Note SO-57, 6 pp., illus.

Van Sickle, C. C. 1967. Forest industries in Appalachia counties of Tennessee. Southern Forest Expt. Sta., New Orleans, La. U.S. Forest Service Resource Bull. SO-8, 21 pp.

Wall, Brian R. 1967. 1966 Oregon timber harvest. Pacific Northwest Forest & Range Expt. Sta., Portland, Oregon. U.S. Forest Service Resource Bull. PNW-22, 2 pp., illus.

Wall, Brian R. 1967. 1966 Washington timber harvest. Pacific Northwest Forest & Range Expt. Sta., Portland, Oregon. U.S. Forest Service Resource Bull. PNW-21, 2 pp., illus.

Welch, Richard L. 1967. Five-year trend in the price of pulpwood in the Southeast, 1962-66. Southeastern Forest Expt. Sta., Asheville, N.C. U.S. Forest Service Research Note SE-81, 2 pp.

Wilson, Robert W., Jr., and Peters, Robert C. 1967. The northeastern forest-inventory data-processing system. II. Description of subsystem EDIT. Northeastern Forest Expt. Sta., Upper Darby, Pa. U.S. Forest Service Research Paper NE-70, 12 pp., illus.

Wilson, Robert W., Jr., and Peters, Robert C. 1967. The northeastern forest-inventory data-processing system. V. Description of subsystem TABLE. Northeastern Forest Expt. Sta. Upper Darby, Pa. U.S. Forest Service Research Paper NE-73, 11 pp., illus.

Wilson, Robert W., Jr., and Peters, Robert C. 1967. The northeastern forest-inventory data-processing system. VIII. Description of subsystem OUTPUT. Northeastern Forest Expt. Sta., Upper Darby, Pa. U.S. Forest Service Research Paper NE-76, 7 pp., illus.

Wong, W. H. C., Jr.; Honda, Nobuo; and Nelson, R. E. 1967. Plantation timber on the Island of Lanai--1966. Pacific Northwest Forest & Range Expt. Sta., Portland, Oregon. U.S. Forest Service Resource Bull. PSW-7, 18 pp., illus.

FOREST ECONOMICS

USDA and Cooperative Program

Location of Intramural Work	Scientist Man-Years F.Y. 1968			
	Research Problem Area			Total
	108	303	903	
Arizona	4.0			4.0
Arizona	2.0			2.0
California			4.1	4.1
Louisiana		5.2		5.2
Minnesota		3.0		3.0
Ohio		5.0		5.0
Oregon		3.3		3.3
Pennsylvania		2.0		2.0
Utah		3.1		3.1
Washington		1.0		1.0
Total	6.0	22.6	4.1	32.7

Intramural program is supplemented by extramural support representing (a) 0 SMY's at State Agricultural Experiment Stations, (b) 0 SMY's at other U.S. institutions and (c) P.L. 480 funds in 0 countries representing 0 U.S. dollars equivalent.

Problems and Objectives

Currently, about $700 million is spent annually by forest owners on the management of forest lands for timber production. Substantial amounts also are being spent on programs to meet rapidly rising demands for recreation, water, wildlife, and other forest goods and services. Most expenditures are made on the public and industrial ownerships that include about 40 per cent of the commercial forest land. The level of management on several million farm and miscellaneous private ownerships, which collectively include 60 percent of the commercial forest area, is generally low. These farm and miscellaneous ownerships are strategically located and potentially highly productive. They are of key importance in meeting the Nation's rising demands for timber, recreation, and other forest products.

The general objectives of Forest Economics research are to:

1. Develop economic criteria for the efficient allocation of the hundreds of millions of dollars being spent on the management of forest lands,
2. Determine the size and combination of forestry programs that would most effectively and cheaply supply the Nation's future demands for timber and other forest products,
3. Provide management guides for integrating and balancing multiple uses of forest land to meet the rapidly expanding demands for timber, water, wildlife, recreation, and other forest related goods and services, and
4. Identify the most effective programs for stimulating the millions of farm, miscellaneous, and private owners to follow productive management practices.

Progress--USDA and Cooperative Programs

1. New capital budgeting techniques for the allocation of capital. A new method of allocating capital to resource programs, based on marginal rather than on average rates of return on investments, has been developed. Use of this method will help achieve efficient allocation of capital among various investment projects, both in forestry projects and in other investments.

2. High returns from expenditures for timber stand improvement. A study of investment opportunities in the loblolly-shortleaf pine type of Georgia shows that returns up to 30 percent can be obtained from investments in timber stand improvement practices. The lowest rate of return on the five-stand categories included in the study was 16 percent. The analysis suggests that forest land owners might increase their forestry activities if fully informed about potential returns from timber stand improvement.

3. Conventional boltwood logging operations most economical in thinning red pine plantations. As part of our analysis of returns from plantation investments, comparisons of time study statistics indicate that conventional boltwood logging operations are somewhat more economical than tree-length methods for harvesting pulpwood in thinning red pine plantations. At $1.50 per hour and using a 2-man boltwood operation, a cord of pulpwood can be harvested and stacked at roadside for a labor cost of $10.26 (5-inch trees) to $6.57 (9-inch trees). Labor costs for 2-man tree-length logging varied from $10.98 (5-inch trees) to $7.65 (9-inch trees).

4. More effective cost-control systems for the National Forests in the northern Rockies. A cooperative study by the Northern Region of the Forest Service and the Intermountain Forest and Range Experiment Station resulted in the development of an effective cost-control system for timber growing on the National Forests. Improvements were made by establishing information systems for the forest resource, planning of work programs, and collection of cost data. Techniques for developing cost-saving equations with the help of electronic data equipment were also developed.

In a related study, various species were evaluated for planting western white pine sites on National Forest lands. Two computer programs were developed for use in ranking alternative species and management programs. A system was also developed for ranking treatment opportunities in existing timber stands.

5. Essential features of 56 special forest tax laws summarized. A report published in early 1968 summarizes in nontechnical language the essential features of 56 special forest tax laws effective in 33 States and the Commonwealth of Puerto Rico as of December 31, 1967. In recent years the most significant development in forest taxation has been the modification of the property tax to permit assessment in "present use" as contrasted with "highest and best use;" in some States this development has significant rural land use planning and zoning aspects. There has been little change in the number of States with yield tax laws although there have been some gains in the area to which yield taxes apply.

6. Large variation in the timber dependency of economic areas in the Douglas-fir Region. Timber dependency in 15 economic areas comprising the Douglas-fir Region, as measured by employment in timber-dependent industries, ranged from 6.2 percent in the Seattle area to 99.4 percent in the Roseburg area. Timber dependent industries accounted for about 45 percent of the economic base employment in the Douglas-fir Region.

7. Operations research models can be used in determining allowable cut. A new study in the Pacific Southwest has shown that operations research models can be used in determining the allowable cut of timber in a manner which will account for various factors such as capital requirements, mill

capacity or deficit maximization. Consideration of these influences can insure more rational management of both public and private forests.

Publications - USDA and Cooperative Program

RPA 108 - ECONOMICS AND LEGAL PROBLEMS OF WATERSHEDS

Barger, Roland L. and Ffolliott, Peter F. 1967. Multiproduct timber inventory. Rocky Mountain Forest & Range Expt. Sta., Ogden, Utah. Paper presented at 21st annual meeting of the Forest Products Research Society, July 1967, Vancouver, B.C., mimeo. 12 pp.

Ffolliott, Peter F. and Barger, Roland L. 1967. Occurrence of stem features affecting quality in cutover Southwestern ponderosa pine. Rocky Mountain Forest & Range Expt. Sta., Ogden, Utah. USFS Research Paper RM-28, 11 pp., illus.

Price, Raymond. 1967. Possibilities of increasing streamflow from forest and range watersheds by manipulating the vegetative cover. Rocky Mountain Forest & Range Expt. Sta., Ogden, Utah. Paper presented at International Union of Forestry Research Organizations, XIV IUFRO-Congress, Section 01-02-11, pp. 487-504, illus. Munich, West Germany.

Williams, John A. and Anderson, Truman C., Jr. 1967. Soil survey of Beaver Creek Area, Arizona. Rocky Mountain Forest & Range Expt. Sta., Ogden, Utah. USDA Forest Service and Soil Conservation Service cooperating with Arizona Agr. Expt. Sta., GPO, Washington, D. C. 75 pp., illus.

RPA 303 - ECONOMICS OF TIMBER PRODUCTION

Anderson, W. C. 1968. Rating investments for improving Georgia timber stands. Southern Forest Expt. Sta., New Orleans, La. Land Economics XLIV(1): 121-127. February.

Anderson, W. C. 1967. Upcoming wood-procurement problems for Alabama pine sawmills. Southern Forest Expt. Sta., New Orleans, La. Alabama Forest Prod. 10(7): 25-27, illus.

Bentley, W. R., and Kaiser, H. F. 1967. Sequential decisions in timber management--a Christmas tree case study. Southern Forest Expt. Sta., New Orleans, La. Journal of Forestry 65: 714-719, illus. Oct., 1967.

Chappelle, D. E. 1967. Financial maturity of eastern white pine in New York State. Northeastern Forest Expt. Sta., Upper Darby, Pa. State Univ. College of Forestry at Syracuse University Tech. Pub. 91. 261 pp., illus.

Chappelle, Daniel E. 1967. Trichotomy of sciences. Pacific Northwest Forest & Range Expt. Sta., Portland, Oregon. Western Forester 13(2): 1, 3.

Christopher, J. F., and Guttenberg, S. 1967. Timber conversion factors and economic break-even points. Southern Forest Expt. Sta., New Orleans, La. American Pulpwood Assoc. Tech. Papers, Oct. Paper 67-21: (7236) pp. 21-23.

Guttenberg, S. 1967. Converting forest resource statistics to timber supply. Southern Forest Expt. Sta., New Orleans, La. Proc. Seventh Conf. on Southern Ind. Forest Manage., pp. 46-51. Duke Univ., Durham, N. C.

Guttenberg, S. 1967. Economic implications of weight scaling. Southern Forest Expt. Sta., New Orleans, La. Southern Lumberman 214(2663): 33-34, 36, illus. April 1, 1967.

Guttenberg, S. 1967. Growth prospects for the forest industries in the South--In meeting the challenge of today's markets. Southern Forest Expt. Sta., New Orleans, La. Proc. 4th Annual Forest Ind. Marketing Conf., Univ. Oregon. pp. 166-171. Also in Southern Lumberman 215 (2670): 20, 22. and Oregon Business Review XXVI(9): 1-3.

Guttenberg, S. 1967. How increased demand can improve Area I timber supply. Southern Forest Expt. Sta., New Orleans, La. Papers presented at Area I meeting of South. Pulpwood Conserv. Assoc., Hot Springs, Ark., pp. 1-4.

Guttenberg, S. 1967. Veneer yields from southern pine bolts. Southern Forest Expt. Sta., New Orleans, La. Forest Products Journal 17(12): 30-32, illus. Dec.

Manthy, R. S. 1967. Dynamic concepts of timber requirements and availability. Northeastern Forest Expt. Sta., Upper Darby, Pa. Southern Industrial Forest Management Proceedings, 7th Conf., Duke Univ., pp. 38-46.

Manthy, R. S., Lemmiem, W. A., Rudolph, V. J., and James, L. M. 1967. A time study for plantation logging. Northeastern Forest Expt. Sta., Upper Darby, Pa. Michigan State Univ. Agriculture Expt. Sta. Quarterly Bull. 49(3): 328-341, Article 49-31.

McCauley, Orris D., and Whittaker, James C. 1967. Sawmill practices and problems in the Appalachian Hill Country of Ohio and Kentucky. Northeastern Forest Expt. Sta., Upper Darby, Pa. USFS Research Paper NE-80, 15 pp., illus.

McCauley, Orris D., and Whittaker, James C. 1967. The value added by sawmilling in the Appalachian Hill Country of Ohio and Kentucky. Northeastern Forest Expt. Sta., Upper Darby, Pa. USFS Research Note NE-67, 4 pp., illus.

Mendel, Jospeph J. 1967. Forestry accomplishments in southeastern Ohio under the U.S. Agricultural Conservation Program, 1957-64. Northeastern Forest Expt. Sta., Upper Darby, Pa. USFS Research Paper NE-65, 23 pp., illus.

Nelson, T. C. 1967. The forest situation in the South. Southern Forest Expt. Sta., New Orleans, La. Forest Farmer XXVII (3): 9-10. December 1967.

Pleasonton, A. 1967. The forestry consultant: an analysis. Southern Forest Expt. Sta., New Orleans, La. Forest Farmer 27(1): 10, 12, 19, illus. October. Also in The Consultant 13(2): 14-19, April 1968.

Rickard, Wesley M.; Hughes, Jay M.; and Newport, Carl A. 1967. Economic evaluation and choice in old-growth Douglas-fir landscape management. Pacific Northwest Forest & Range Expt. Sta., Portland, Oregon. USFS Research Paper PNW-49, 33 pp., illus.

Sassaman, Robert W., and Chappelle, Daniel E. 1967. A computer program for calculating allowable cut using area regulation and a comparison with the ARVOL method. Pacific Northwest Forest & Range Expt. Sta., Portland, Oregon. USFS Research Note PNW-63, 7 pp., illus.

Schweitzer, Dennis L. 1967. A computer program for preliminary data analysis. North Central Forest Expt. Sta., St. Paul, Minn. USFS Research Note NC-33, 4 pp., illus.

Schweitzer, Dennis L. 1967. A graphical aid in meeting relative standards of precision. North Central Forest Expt. Sta., St. Paul, Minn. Journal of Forestry 65(10): 738.

Schweitzer, Dennis L., and Lindell, Gary R. 1968. Product diversification and income stability. North Central Forest Expt. Sta., St. Paul, Minn. Forest Products Journal, Vol. 18, No. 4, pp. 61-65, illus., April 1968.

Schweitzer, Dennis L., and Lundgren, Allen L. 1967. Reader comment on "A flexible computer program for tabulation of compound interest factors" by Fleischer and Fang. North Central Forest Expt. Sta., St. Paul, Minn. Journal of Industrial Engineering 13(12): 723.

Siegel, W. C. 1967. Federal land bank timber loans in the United States. Southern Forest Expt. Sta., New Orleans, La. USFS Research Paper SO-29, 22 pp., illus.

Siegel, W. C. 1967. Some recent tax developments affecting the timberland owner. Southern Forest Expt. Sta., New Orleans, La. Forest Farmer 26(12): 6-7, 17-19, August 1967.

Siegel, W. C., and Guttenberg, S. 1968. Timber leases and long-term cutting contracts in the South. Southern Forest Expt. Sta., New Orleans, La. Forest Industry 95(4): 62-64.

Williams, Ellis T. 1968. Progress in the assessment of forest land and timber, 1956-1966. Forest Service, Washington, D. C. Reprint from Assessors Journal, pp. 25-35, January 1968.

Williams, Ellis T. 1967. Review of Royal Forest--A history of Deans Woods as producers of timber. U.S. Forest Service, Washington, D. C. Forest Science 13(3): 326., September 1967.

Williams, Ellis T. 1968. State Forest Tax Law Digest, 1967. USDA Forest Service, Washington, D. C. Misc. Pub. 1077, 56 pp., illus. March 1968.

Williams, Ellis T. 1967. State guides for assessing forest land and timber, 1966. USDA Forest Service, Washington, D. C. Misc. Pub. 1061, 91 pp., illus.

Williams, Ellis T. 1967. Valuation of forest land and timber under the property tax in the United States. Forest Service, Washington, D. C. Proc. XIV IUFRO-Congress, Section 31, Vol. 8, pp. 240-256. Munich, West Germany 1967.

RPA 903 - MULTIPLE USE POTENTIALS OF FOREST LANDS

Amidon, Elliot L., and Akin, Garth. 1968. Dynamic programming to determine optimum levels of growing stock. Pacific Southwest Forest & Range Expt. Sta., Berkeley, Calif. (Accepted for publication in Forest Science)

McConnen, R. J. 1967. The use and development of America's forest resources. Pacific Southwest Forest & Range Expt. Sta., Berkeley, Calif. Reprint from Economic Botany, Vol. 21, No. 1, January-March 1967, 14 pp.

McConnen, R. J., Amidon, E. L., and Navon, D. I. 1967. The use of operation research techniques in determining allowable cut. Pacific Southwest Forest & Range Expt. Sta., Berkeley, Calif. Proceedings of Society of American Foresters Meeting, Seattle, Washington, 1966, pp. 109-115.

Navon, Daniel I., and McConnen, Richard J. 1967. Evaluating forest management policies by parametric linear programming. Pacific Southwest Forest & Range Expt. Sta., Berkeley, Calif. USFS Research Paper PSW-42, 13 pp., illus.

FOREST PRODUCTS MARKETING

USDA and Cooperative Programs

Location of Intramural Work	Scientist Man-Years F.Y. 1968			
	Research Problem Area			Total
	502	513	801	
California	1.8			1.8
Colorado	2.0			2.0
Georgia			4.0	4.0
Illinois	3.0			3.0
Minnesota	5.2			5.2
Montana	2.0			2.0
Oregon	3.0			3.0
West Virginia	13.0			13.0
Washington		6.0		6.0
Total	30.0	6.0	4.0	40.0

Intramural program is supplemented by extramural support representing (a) 1.5 SMY's at State Agricultural Experiment Stations, (b) 0.5 SMY's at other U.S. institutions and (c) P.L. 480 funds in 0 countries representing 0 U.S. dollars equivalent

Problems and Objectives

Timber and timber products are important sources of income and employment for several hundred thousand forest owners, processors, and distributors, and a basic raw material in houses, furniture, and other products used by millions of consumers. The present contribution of the timber resource can be substantially increased. There are unused hardwood timber resources in the North and softwood resources in the South, the Rocky Mountains, and Coastal Alaska which could support more timber-based industries, provide additional employment for local people, and increase the income of forest owners, processors, and distributors.

The general objectives of the Forest Products Marketing research are to:

1. Increase the economic benefits from timber to producers and consumers by developing ways of reducing costs of harvesting, processing, distributing, and using timber products,
2. Expand markets for timber products and stimulate timber-based industrial development in areas where timber is available, especially in economically depressed forested areas such as Appalachia, the Rocky Mountains, and the northern Lake States, and
3. Through appraisals of present and prospective trends in the use of timber products, provide guides for marketing and investment decisions of public agencies, forest land managers, and timber product manufacturers.

Progress--USDA and Cooperative Programs

1. Rapidly growing demands point to increasing competition for wood. Projections in a new Forest Service study indicate the demand for paper and board will nearly double by 1985. The related demand for pulpwood in U.S. mills by 1985 is estimated at about 120 million cords--some 2.2 times the 55.4 million cords used in 1966.

Given an increase in the demand for pulpwood of this general magnitude, and assuming the cut of other timber products and the level of forest management would be about the same as in the recent Forest Service study Timber Trends in the United States, total projected demands for timber would rise above available timber supplies sometime around 1980. Prospective shortages in subsequent years, especially in the size and quality of trees most needed by industry, would intensify competition for timber and lead to higher harvesting and processing costs. This would particularly affect the lumber and veneer industries which require relatively large-sized and high-quality timber.

Wood needs of the pulp and paper industry could be met in the foreseeable future by expanding programs to grow more trees, use more hardwoods, and improve technology in the use of available material. Rural communities in all regions would benefit from such increases in timber production.

2. Deficit in timber trade in 1967 near $1 billion. In 1967 the total value of U.S. imports of timber products was $2.1 billion. Values of exports of wood products amounted to nearly $1.2 billion. Net imports of about 1.2 billion cubic feet represented about 9 percent of the total consumption of timber products in the United States. Newsprint, wood pulp, lumber and hardwood plywood were the most important items in the import trade. Paper and board, wood pulp, and softwood logs accounted for most of the export trade.

Projections of world timber demands indicate a continuing growth in export markets--especially for paper and board, wood pulp, and softwood plywood. The United States has the potential to substantially increase such exports and at the same time supply most domestic needs. However, achievement of this goal will require large investments in forest management programs to grow more timber on the Nation's forest lands.

3. Appearance, performance, and cost principal considerations of builders in choosing materials for housing. There is wide variation in the use of wood in new one-family houses. Wood window units, for example, are preferred in the North and East, in part because of certain style and performance advantages, whereas, problems of paint maintenance in the South and Southwest limit the use of wood windows in these areas. Wood-based sidings are used extensively in the North and Northeast, but nonwood sidings are strong competitors in all areas. Lumber is the predominant shelving material in new homes, but there is a growing interest in new shelving materials to overcome problems of warping and to reduce installed costs. Overall appearance, performance, and costs are the principal considerations of builders when selecting windows, siding, and shelving.

4. Second homes add in an important way to the demand for housing and timber products. Residential construction is the Nation's largest market for lumber, plywood, and other timber products. In recent years there have been indications that the construction of second homes has been adding in an important way to the demand for residential units. This is borne out by a newly completed survey. This survey, co-sponsored by the Forest Service and the Bureau of the Census, shows that 1.7 million households, out of a total of 59 million in the United States, have second homes. The survey also indicated that about 300,000 households expected to buy or build second homes within two years. This will add to the demand for housing that is building up, increase the competition for timber, and intensify the upward pressure on stumpage and product prices.

5. Particleboard could find wider acceptance in wood-using industries. A Co-op Aid Study between the North Central Forest Experiment Station and the Department of Forest Products at Michigan State University showed that acceptance of particleboard by the furniture and cabinet industry is variable. Some firms readily use this product while others have experienced problems attributable to either physical or economic factors. The report suggests that particleboard could find wider acceptance if it is recognized as a unique product and its use planned accordingly rather than viewed simply as a substitute for other core materials.

6. Chip production profitable in hardwood sawmills. A case study of 7 selected hardwood sawmills in Ohio, Kentucky, and Tennessee showed that, at current chip prices, chip production yielded a profit in 5 of the 7 cases examined. When the reduction in lumber production costs attributable to chipping operations was considered along with the returns from chips, chipping operations proved profitable in every case.

7. Hardwood sawmills make important economic contributions in Appalachia. The hardwood sawmill industry is recognized as an important source of employment and income in the generally depressed Appalachian area, but few data exist to show its actual economic contribution to the region. A study of costs and returns from the production of lumber at 40 sample sawmills in southeastern Ohio and eastern Kentucky indicated that sawmilling alone adds about $12.8 million annually to that area's economy.

8. New system developed for leveling old floors in apartment buildings. The use of prefabricated kitchen and bathroom units and other assemblies for speedy rehabilitation of apartment buildings requires level floors, but many old floors sag or tilt badly. A rapid, low-cost method to level such floors has been developed. A quick-leveling device of tubular aluminum holds 2 x 2-inch wooden screeds in position while a quick-hardening foam is sprayed in place beneath the screeds, supporting them and bonding them to the old floor. The screeds then serve as a support for a finished strip or panel flooring. Two men can install the screeds in a room 12 x 12 feet at a total cost of 7 cents per square foot for labor and materials. The use of this system to level floors in the 43,000 apartment buildings in a New York City Urban Rehabilitation Project alone would save 27 million man-hours and $120 million over the system previously used.

9. Study highlights problems of forest cooperatives. A new analysis of the experience of forestry cooperatives shows that most of the forest cooperatives established in the United States in the past 50 years have gone out of business. Most failures were due to one or more of the following factors: (1) lack of adequate volume of business, (2) lack of interest and support by members, (3) inadequate management, and (4) lack of capital for initial and working investments.

10. Board industries growing rapidly. The annual capacity of the Nation's particleboard industry has increased nearly 8 times in the last decade and a half and now totals over a billion square feet. In the same period, the annual capacity of plants making insulation board and hardboard increased from 2 million tons to 3.3 million tons.

Publications - USDA and Cooperative Program

RPA - 502 DEVELOP MARKETS FOR TIMBER

Adams, Thomas C. 1968. Price trends of open-market Douglas-fir logs in western Washington and northwest Oregon. Pacific Northwest Forest & Range Expt. Sta., Portland, Oregon. USFS Research Note PNW-74, 6 pp., illus.

Benson, Robert E. 1967. Montana Christmas trees: over 80 million in three decades. Intermountain Forest & Range Expt. Sta., Missoula, Montana. American Christmas Tree Journal, August 1967.

Benson, Robert E., and Kirkwold, Larry L. 1967. Market trends for western white pine. Intermountain Forest & Range Expt. Sta., Ogden, Utah. USFS Research Note INT-65, 8 pp., illus.

Dempsey, Gilbert P. 1967. Forest cooperatives: a bibliography. Northeastern Forest Expt. Sta., Upper Darby, Pa. USFS Research Paper NE-82, 53 pp.

Dempsey, Gilbert P. 1968. Some new guidelines for the forest cooperative. Northeastern Forest Expt. Sta., Upper Darby, Pa. Journal of Forestry 66(1): 17-21, illus. Jan. 1968.

Eads, Larry D. 1967. Furniture species--a forecast of tomorrow's trends. Northeastern Forest Expt. Sta., Upper Darby, Pa. Forest Products Journal, Vol. 17, No. 8, pp. 10-11, August 1967.

Eads, Larry D. 1967. Furniture species--yesterday, today, and tomorrow. Northeastern Forest Expt. Sta., Upper Darby, Pa. Upholstering Industry, pp. 8, 10, 20, 40, 43, 45-49, April 1967.

Ellefson, Paul V. 1967. Christmas tree marketing: a bibliography. Northeastern Forest Expt. Sta., Upper Darby, Pa. American Christmas Tree Journal 11(2): 15-27, illus., May 1967.

Ellefson, Paul V., and Wisdom, Harold W. 1967. Present costs determine future Christmas tree profits. Northeastern Forest Expt. Sta., Upper Darby, Pa. American Christmas Tree Journal 11(2): 9-14, illus., May 1967.

Hamilton, Thomas E. 1967. Production, prices, employment and trade in Pacific Northwest forest industries. (Quarterly). Pacific Northwest Forest & Range Expt. Sta., Portland, Oregon.

Herrick, Owen W., and Christensen, W. W. 1967. A cost analysis of chip manufacture at hardwood sawmills. Northeastern Forest Expt. Sta., Upper Darby, Pa. USFS Research Paper NE-69, 14 pp., illus.

Kallio, Edwin, and Sesco, Jerry A. 1967. Residential fencing in a metropolitan area and three small towns. North Central Forest Expt. Sta., St. Paul, Minn. USFS Research Paper NC-14, 8 pp., illus.

Kotok, E. S., and Benson, R. E. 1967. 100-level construction...a novel marketing concept. Intermountain Forest & Range Expt. Sta., Missoula, Montana. Forest Products Journal 17(9): Sept. 1967.

Lucas, John T. 1967. Wooden pallet requirements by Department of Defense. Northeastern Forest Expt. Sta., Upper Darby, Pa. Southern Lumberman 214(2665): 13-16, May 1967.

Martens, David G. 1967. How lumber price changes affect sawlog values. Northeastern Forest Expt. Sta., Upper Darby, Pa. USFS Research Paper NE-87, 38 pp., illus.

Martens, David G., and Craft, E. Paul. 1967. The MARCRAFT floor-leveling system for urban rehabilitation. Northeastern Forest Expt. Sta., Upper Darby, Pa. USFS Research Note NE-66, 8 pp., illus.

McCauley, Orris D., and Whittaker, James C. 1967. Sawmill practices and problems in the Appalachian hill country of Ohio and Kentucky. Northeastern Forest Expt. Sta., Upper Darby. USFS Research Paper NE-80, 15 pp., illus.

McCauley, Orris D., and Whittaker, James C. 1967. The value added by sawmilling in the Appalachian hill country of Ohio and Kentucky. Northeastern Forest Expt. Sta., Upper Darby, Pa. USFS Research Note NE-67, 4 pp., illus.

Norton, Kenneth. 1967. Economic and related marketing information on the forced-air drying of eastern spruce and hemlock. Northeastern Forest Expt. Sta., Upper Darby, Pa. Univ. of Massachusetts, Amherst, Mass. Masters Degree Thesis, 123 pp., illus., mimeo.

Schweitzer, Dennis L., and Lindell, Gary R. 1968. Product diversification and income stability. North Central Forest Expt. Sta., St. Paul, Minn. Forest Products Journal 18(4): 61-65, illus. April 1968.

Sesco, Jerry A., and Dunmire, Daniel E. 1967. Market opportunities for hickory stadium seat slats. North Central Forest Expt. Sta., St. Paul, Minn. Southern Lumberman, Vol. 215, No. 2680, pp. 165-166, Dec. 15, 1967.

Sesco, Jerry A., and Kallio, Edwin. 1967. Stadium seating: A market analysis. North Central Forest Expt. Sta., St. Paul, Minn. USFS Research Paper NC-11, 11 pp., illus.

Suchsland, Otto W. 1968. The selection of panel materials by furniture and cabinet manufacturers. Unnumbered publication. Michigan Agricultural Expt. Sta. 170 pp. Jan. 1968. (Co-op Aid study between North Central Forest Expt. Sta. and Dept. of Forest Products at Michigan State Univ.)

Yerkes, Vern P., Lloyd, R. Duane, and Lewis, Gordon D. 1968. Softwood plywood in the United States--production and distribution in 1965. Rocky Mountain Forest & Range Expt. Sta. USFS Research Paper RM-34, 23 pp., illus.

Zinnikas, John D., and Boone, R. Sidney. 1967. Markets for Hawaii hardwood lumber in new single-family houses on Oahu, Hawaii. Pacific Southwest Forest and Range Expt. Sta. USFS Research Paper PSW-41, 10 pp., illus.

Zinnikas, John D., and Boone, R. Sidney. 1967. Requirements for new housing in Hawaii, 1965-70...a forecast. Pacific Southwest Forest & Range Expt. Sta., Berkeley, Calif. USFS Research Paper PSW-40, 6 pp., illus.

RPA - 513 SUPPLY-DEMAND ANALYSIS

Gill, Thomas G., and Phelps, Robert B. 1967. Wood preservation statistics, 1966. U.S. Forest Service in cooperation with American Wood-Preservers' Association. Reprint of Wood Preservation Statistics published in 1967. Volume of the AWPA Proceedings, 35 pp.

Hair, Dwight. 1967. Use of regression equations for projecting trends in demand for paper and board--with projections of demand to 1985 for major grades of paper and board, wood pulp and pulpwood. U.S. Forest Service, Washington, D. C. USDA-FS Forest Resource Report No. 18, 178 pp., illus.

Hair, Dwight and Ulrich, Alice H. 1967. The demand and price situation for forest products, 1967. U.S. Forest Service, Washington, D. C. USDA-FS Misc. Pub. 1066, 72 pp., illus.

Wright, Maurice G., and Phelps, Robert B. 1967. Trends in particleboard, insulation board and hardboard industries, 1956-66. U.S. Forest Service, Washington, D. C. USFS Research Paper WO-5, 22 pp., illus.

RPA - 801 HOUSING

Lawrence, J. D., and Dyson, P. J. 1967. Estimating logging costs based on rate of output. Southeastern Forest Expt. Sta., Athens, Ga. Georgia Forest Research Council, Georgia Forest Research Paper No. 48, 5 pp., September.

Prestemon, Dean R. 1968. How much does noise bother apartment dwellers? Architectural Record, February 1968, 2 pp., illus.

Prestemon, Dean R. 1968. Least-cost wall and floor constructions for limiting transmission of noise. Iowa State University of Science and Technology, Department of Forestry, Ames, Iowa. Special Report No. 55, 16 pp. February 1968.

Sampson, G. R. 1967. Markets for wood in remodeling and repair. Southeastern Forest Expt. Sta., Athens, Ga. Southern Lumberman 215(2680): 161-162, Dec. 1967.

Sampson, G. R. 1967. Residential remodeling and repair: Big market for wood. Southeastern Forest Expt. Sta., Athens, Ga. Forest Products Journal 17(7): 13-15, July 1967.

Sampson, G. R., and Fasick, C. A. 1967. Southern pine glulam industry: Market status. Southeastern Forest Expt. Sta., Athens, Ga. Forest Products Journal 17(11): 11-13, Nov. 1967.

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